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Prior to the successful Joint Annual Meeting of the Entomological Societies of Ontario and Canada in Guelph your Board met and discussed how to improve the profile of JESO amidst all the competition from the numerous new electronic journals. In his 1999 editorial, past editor Dolf Harmsen had foreseen some of the problems the Proceedings would face with the advent of electronic publishing. Since then, past editor Miriam Richards overcame some of the hurdles and for almost a decade JESO has been publishing electronically. It continues to be printed as hard copy as well. Having both formats has its merits and for historical reasons–it is one of the longest running entomology journals in the world, with no publication breaks since 1871–the hard copy will continue to be published. It is an important part of ESO's heritage. Greater visibility for JESO on the internet is now needed and some good ideas for obtaining this were presented. Ideas for improving JESO's impact were also discussed. One action approved by the Board and promptly implemented by past president Jeff Skevington was to sign an agreement with the Biodiversity Heritage Library to have all back issues scanned, starting with Volume 1 of the Annual Report and make them available on the website, with a two year embargo on the most recent volume.

This year's volume contains five scientific notes and one scientific paper. All but one (on taxonomy) report new species records for Ontario, new distributions or new host records. Two papers are overviews of the past 60 years of JESO papers on two topics. One, on Taxonomy and Faunistics, is mostly a summary. The other, much more detailed and comprehensive is on Biological Control. Both were written to commemorate the 150th meeting of ESO. If there is any trend in the kinds of papers submitted in recent years it is more towards more papers in these areas of entomology and fewer on economically important pest species and their control. Papers on all aspects of entomology are, of course, welcome and my hope is that you, the readers, will continue to find JESO a good place to publish your research.

John T. Huber
Editor

NEW RANGE RECORDS OF MOSQUITOES (DIPTERA: CULICIDAE) FROM NORTHERN ONTARIO

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Abstract *J. ent. Soc. Ont.* 144: 3–14

A survey for mosquitoes at 23 sites in the Ontario Shield and Hudson Bay Lowlands of northern Ontario, Canada, in 2011 and 2012 yielded 19 species, including 16 of *Aedes*, and one each of *Anopheles*, *Coquillettidia*, and *Culesita*. One species, *Aedes pullatus* (Coquillett) is newly recorded for Ontario. Eleven northern range extensions and one southern range extension are reported.

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Introduction

The distributions of many mosquito species (Diptera: Culicidae) in Canada are incomplete. Jenkins and Knight (1952) conducted a survey of larval mosquitoes in southern James Bay. Steward and McWade (1960) published range summaries of species in Ontario. Wood et al. (1979) compiled the most complete account of mosquito distribution in Canada The Canadian Endangered Species Conservation Council (CESCC 2011) assessed the status of many species, including mosquitoes. Yet, areas such as northern Ontario are still relatively little sampled.

Northern Ontario has become the focus of increased mineral exploration and development (FNSAP 2010). Additionally, the area is projected to undergo significant ecological transformation over the next several decades due to climate change (FNASP 2010). Together, these two driving forces create a need for better knowledge of species' distributions in northern Ontario before significant changes occur. A biological diversity survey of different taxa in northern Ontario was initiated in 2009 to address this issue (OMNR 2012). The species composition and diversity information obtained will help determine land use, and management and conservation planning, as well as provide baseline information to determine the impact of mining and climate change.

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Mosquito species lists for particular geographic areas include species that have not been collected there but are assumed to be present based on information from adjacent areas (e.g., Wood et al. 1979; Darsie and Ward 2005). Thus, it is reasonable to expect species to be found in northern Ontario if they have been found in similar habitats and at similar latitudes elsewhere, i.e., in spite of regional climatic differences, we expected to find species that have existing records from both adjacent western Quebec and northern Manitoba because of the large scale continuity of the ecosystems in the boreal and subarctic forests that span these three provinces. For mosquito species whose known distributional limits were either south or north of our study areas, we expected to extend known ranges north or south, respectively. Following this reasoning, and based on the range maps provided by Wood et al. (1979) and Darsie and Ward (2005), we predicted a maximum of 31 species in our surveys. In this paper we report new information on occurrences of known species (range extensions), new collection locations and records of species new to the province for Culicidae in Ontario from surveys of previously unexplored areas of the far north of Ontario. We use both rarefaction and a lognormal analysis to explore the maximum number of species predicted in these areas and to gauge their relative abundances.

Materials and Methods

Sampling took place within two different northern Ontario ecozones: the Ontario Shield and Hudson Bay Lowlands ecozones (Crins et al. 2009) in 2011 and 2012, hereafter referred to the western and eastern study areas, respectively, as part of a larger biological survey of animal and plant taxa undertaken by the OMNR (2012). The 2011 sampling occurred within 150 km of the First Nations communities near Big Trout Lake and Sandy Lake in the western study area. The 2012 sampling occurred within 150 km of the First Nations community of Fort Albany in the eastern study area. In each year 12 sample sites were randomly selected from the computer generated grid of National Forest Inventory (NFI) points (Gillis et al. 2005). Actual sample locations sometimes differed by as much as 15 km from the NFI coordinates depending on feasibility of landing a helicopter. Our plot locations are the sites at which field camps were established (OMNR 2012). Sample locations were within 1 km of the field camp, which was verified using a handheld GPS (Garmin Rino 530HCx, NAD83, ±3m accuracy). Sampling occurred from 29 May to 17 July in 2011 and 4 June to 5 July in 2012.

Habitats at these sites were dominated by coniferous and shrub wetlands comprised largely of black spruce (*Picea mariana* Britton, Sterns & Poggenb.) and tamarack (*Larix laricina* (Du Roi) K. Koch) as well as shrub and sedge fens, and sphagnum bog. The sites sampled in 2012 in the eastern study area generally had more standing water than those sampled in 2011 in the western study area.

In both years the mosquito component of the sample regimen included daily sampling both by individual collection (*ad hoc*, when mosquitoes were present, approximately 30 minutes total), and a dusk and dawn sweeping with an insect net for 6 minutes at each sampling location. Individual collection consisted of catching mosquitoes that landed on the face, arms, and legs of field crew members using snap cap vials (2.0 ml) before they had a chance to bite. These collections occurred throughout the day and late evening. Individual

specimens in snap vials were preserved dry in the capture vials. Adult mosquitoes collected by sweeping were placed in labeled sample jars with a silica desiccant to prevent deterioration from moisture. A large proportion of them had scales on their thoraces abraded and so could not be identified to species. Therefore, more effort was placed on individual collection in 2012. All specimens were pinned and identified by JLR and DVB using the keys of Wood et al. (1979), and Thielman and Hunter (2007). Nomenclature was based on the WRBU Online Catalog (2013). Voucher specimens were assigned individual specimen numbers (Table 2) and are stored at the Trent University Biology Department in Peterborough, Ontario. Some vouchers are deposited in the Canadian National Collection of Insects, Ottawa.

Analysis

Rarefaction analysis for the 2011 and 2012 catch data was performed using software on the University of Alberta website (http://www.biology.ualberta.ca/jbrzusto/rarefact.php). This method relates sampling effort to number of species caught. The total number of species caught each year is used to calculate the expected number of species (with standard deviation) that would have been caught if fewer mosquitoes were sampled overall. Different species numbers for the same total catch sizes indicate community differences such as those due to site, e.g., habitat or phenological, or procedural differences.

We also fit the catch data (Table 1) to a lognormal distribution using the sum of squares method, i.e., Preston's method as described in Ludwig and Reynolds (1988). This allowed us to calculate the expected number of species by estimating the number of rare species not found in the samples. Essentially, it assumes that species of low abundance, e.g., about 1 per 1000 individuals, will only be found if at least 1000 individuals are collected. The lognormal distribution uses the abundance of different species and groups them into octaves or doubled catch classes, e.g., 0–1 individuals, 1–2 individuals, 2–4 individuals, 4–8 individuals and so on, and fits these frequencies to a lognormal curve by aligning the mode. Species that had only one individual caught could go into either the first or second class, so the number was divided between these classes, e.g., if one catches 5 species with only one individual each, then half of these (2.5) are assigned to the 0–1 class, and 2.5 to the 1–2 class (Ludwig and Reynolds, 1988). One of the assumptions of this method is that very rare species will not be sampled, but can be calculated from the area of the normal curve to the left of the 0–1 class or veil line. The biological interpretation is that this class (0–1) would become the 1–2 class if our total catch size was increased. This analysis requires an iterative method to find values for two parameters that provide the best fit: a (width), and So (height). We used the SOLVER optimization add-in function in Microsoft Excel 2007 version for this task.

Results

We caught 896 mosquitoes in 2011 and 826 in 2012. Mosquitoes caught directly from the face and arms and housed in vials could all be identified to species, whereas only 117 (13%) of individuals from 2011 and 192 (21%) from 2012 sweeping could be identified to species. Species collected and collection locations are summarized in Tables 1 and 2. Twelve species were collected in the western study area in 2011 and 16 species

TABLE 1. Culicidae species collected in 2011 within 150 km of Big Trout Lake and Sandy Lake, and in 2012 within 150 km of Fort Albany.

Species	Catch per year		Date(s) captured		Distribution change for Ontario
	2011	2012	2011	2012	
Aedes abserratus (Felt and Young)	1	29	June 17–July 7	June 8–July 7	gap infill
Aedes canadensis (Theobald)		2		June 25, 28	new northern record
Aedes cinereus Meigen		1		June 23	new northern record
Aedes communis (De Geer)	11	2	June 10, 11	June 15, 28	northwestern gap infill
Aedes dorsalis (Meigen)		4		June 10	new northern record
Aedes excrucians (Walker)	2	2	July 12	June 23, 25	new northern record
Aedes hexodontus Dyar	4	11	June 2–July 12	June 8–13	gap infill
Aedes impiger (Walker)	18		June 2		northwestern gap infill
Aedes implicatus Vockeroth	2	3	June 2–17	June 8, July 10	new northern record
Aedes intrudens Dyar		19		June 8–26	new northern record
Aedes nigripes (Zetterstedt)	1		July 7		new southern record
Aedes pionips Dyar	28	32	June 2–July 7	June 8–July 14	gap infill
Aedes provocans (Walker)		1		June 8	new northern and eastern record
Aedes pullatus (Coquillett)		1		June 10	first record for province
Aedes punctor (Kirby)	7	35	June 6–July 3	June 8–July 7	gap infill
Aedes rempeli Vockeroth		1		June 26	new northern record
Anopheles earlei Vargas	3	5	July 3	June 8, July 13	new northern record
Coquillettidia perturbans (Walker)	39	44	July 3–15	June 17 to July 13	new northern record
Culiseta impatiens (Walker)	1		June 6		new northern record

in the eastern study area in 2012 (Fig. 1, Table 1). The most abundant species identified in both years was *Coquillettidia perturbans* (Walker). Rare species, i.e., those represented by a single individual collected in either year were *Aedes cinereus* Meigen, *Ae. nigripes* (Zetterstedt), *Ae. provocans* (Walker), *Ae. pullatus* (Coquillett), *Ae. rempeli* Vockeroth and *Culiseta impatiens* (Walker).

Fitting to the lognormal distribution (Fig. 2), the expected number of species was 14.75 from the 2011 catches (fitted parameters $a = 0.24$, $So = 2.0$, Chi sq = 1.23, $p = 0.94$, d.f. = 5) and 23.4 species in the 2012 catches (fitted parameters $a = 0.225$, $So = 2.97$, Chi sq = 5.46, $p = 0.36$, d.f. = 5). By combining the two year's totals, our expected number of species for northern Ontario was 28.2 species (fitted parameters $a = 0.21$, $So = 3.35$, Chi sq = 2.94, $p = 0.82$, d.f. = 6).

Interpretations of new records and range extensions are based on comparison with range maps in Wood et al. (1979).

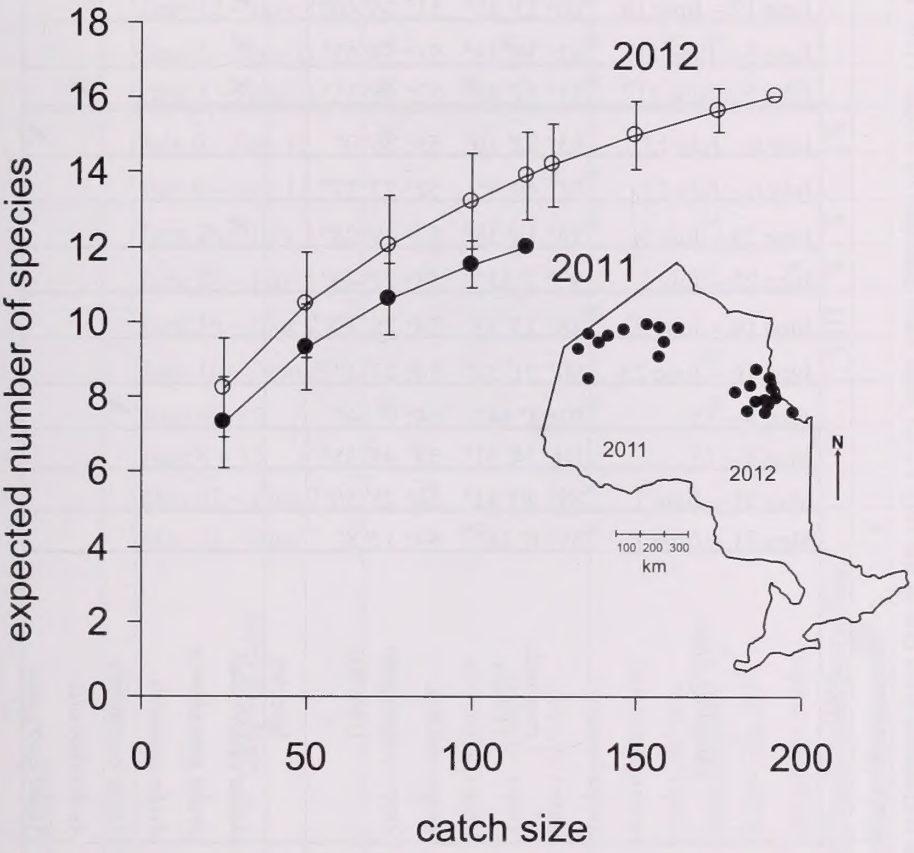

FIGURE 1. Rarefaction analysis of mosquito catches (means and SDs) within 150 km of Big Trout Lake and Sandy Lake in 2011 (closed circles) and within 150 km of Ft. Albany in 2012 (open circles). The inset map of Ontario shows the sampling locations in 2011 and 2012.

TABLE 2. Mosquito species found at each sampling site. Dates indicate when sampling was conducted. Only 11 sample sites listed in 2011 because collections from one of the July 12–21 sites were damaged by a bear. TUIC numbers are voucher specimens in the Trent University Insect Collection.

Year	Sampling dates	Longitude (West)	Latitude (North)	0001 *Aedes abserratus*	0002 *Aedes canadensis*	0003 *Aedes cinereus*	0004 *Aedes communis*	0005 *Aedes dorsalis*	0006 *Aedes excrcians*
2011	May 31 – June 7	89° 6' 28"	53° 12' 8"						
2011	May 31 – June 7	89° 40' 43"	54° 25' 50"						
2011	June 8 – 15	88° 54' 51"	53° 45' 35"						
2011	June 8 – 15	92° 1' 44"	54° 9' 30"				X		
2011	June 16 – June 23	90° 21' 38"	54° 27' 1"						
2011	June 16 – June 23	88° 33' 33"	54° 28' 19"						
2011	June 28 – July 5	93° 2' 33"	53° 27' 40"						
2011	June 28 – July 5	94° 13' 38"	52° 49' 28"	X					
2011	July 6 – July 13	91° 49' 9"	52° 27' 37"						
2011	July 6 – July 13	93° 32' 10"	53° 36' 9"						X
2012	June 5 – June 11	81° 57' 48"	52° 46' 35"	X				X	
2012	June 5 – June 11	82° 39' 13"	51° 55' 53"	X					
2012	June 12 – June 18	80° 23' 11"	51° 26' 40"	X					
2012	June 12 – June 18	81° 50' 57"	51° 39' 8"	X			X		
2012	June 19 – June 25	81° 39' 23"	51° 58' 8"	X		X			X
2012	June 19 – June 25	82° 41' 2"	52° 53' 25"	X					
2012	June 26 – July 2	83° 17' 24"	51° 29' 53"	X	X		X		X
2012	June 26 – July 2	82° 49' 2"	52° 28' 27"						
2012	July 3 – July 9	82° 8' 2"	52° 23' 20"	X					
2012	July 3 – July 9	83° 2' 25"	51° 47' 50"						
2012	July 10 – June 16	83° 22' 44"	52° 18' 23"						
2012	July 10 – July 16	82° 3' 24"	51° 21' 22"						

TABLE 2 continued...

TUIC#	Year	2011										2012											
	Sampling dates	May 31 – June 7	May 31 – June 7	June 8 – 15	June 8 – 15	June 16 – June 23	June 16 – June 23	June 28 – July 5	June 28 – July 5	July 6 – July 13	July 6 – July 13	June 5 – June 11	June 5 – June 11	June 12 – June 18	June 12 – June 18	June 19 – June 25	June 19 – June 25	June 26 – July 2	June 26 – July 2	July 3 – July 9	July 3 – July 9	July 10 – June 16	July 10 – July 16
0007	*Aedes hexodontus*				X						X	X	X			X					X		
0008	*Aedes impiger*		X																				
0009	*Aedes implicatus*	X										X											X
0010	*Aedes intrudens*												X		X	X	X	X					
0011	*Aedes nigripes*									X													
0012	*Aedes pionips*	X	X		X		X		X	X		X	X	X		X	X	X	X	X		X	
0013	*Aedes provocans*											X											
0014	*Aedes pullatus*												X										
0015	*Aedes punctor*				X	X			X				X			X	X	X	X	X	X		
0016	*Aedes rempeli*																	X					
0017	*Anopheles earlei*							X				X									X		
0018	*Coquillettidia perturbans*							X	X		X							X		X	X		X
0019	*Culiseta impatiens*	X																					

New Ontario record

Aedes pullatus has two distinct distributions, an eastern population in northern Quebec and Labrador and the western population in Alberta, British Columbia, and the Yukon (Wood et al. 1979). The single specimen we collected in the eastern study area is the first record in Ontario and extends the range of the eastern population westward.

Northward range extensions

Aedes canadensis (Theobald) is a widely distributed species found in forested regions of all Canadian provinces and the Yukon (Steward and McWade 1960). It is known to be found in Moosonee and Moose Factory in Ontario. Our collection was in the eastern study area.

Aedes cinereus is a common species in Ontario and has been found in Moosonee, Moose Factory and the town of Kenora (Steward and McWade 1960). Jenkins and Knight (1952) noted that *Ae. cinereus* was the most common larval species that they collected in the southern James Bay area but, oddly, they collected no adults. Our single specimen was collected in the eastern study area.

Aedes dorsalis (Meigen) is a rare northern species and in Ontario has only been collected in Moosonee and Moose Factory (Steward and McWade 1960). It was only collected in the eastern study area, which is not surprising because of its relative proximity to these communities.

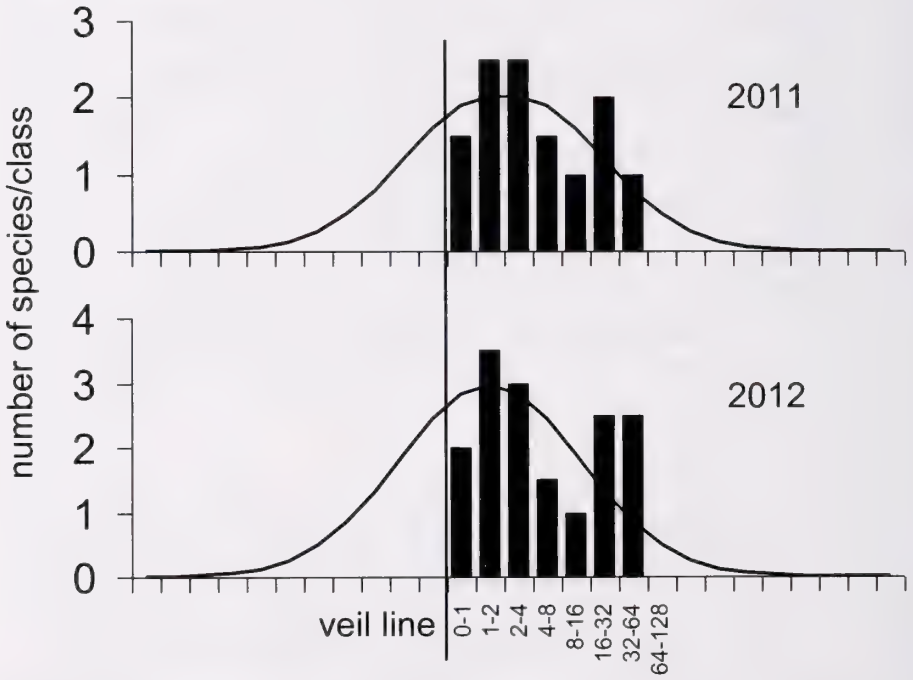

FIGURE 2. Fitted lognormal distributions of mosquito catches within 150 km of Big Trout Lake and Sandy Lake in 2011 and within 150 km of Ft. Albany in 2012. The area of the region left of the veil line represents species that were too rare to be sampled with our methodology.

Aedes implicatus (Vockeroth) is common in the northern and central parts of Ontario and has been collected in Moose Factory (Steward and McWade 1960). It was collected in both study areas.

Aedes excrucians (Walker) is found throughout North America (Wood et al. 1979). It was collected by Jenkins and Knight (1952) in Moose Factory and Moosonee and by Steward and McWade (1960). Our collection from the western study area provides a record for the gap between the eastern James Bay coast and Manitoba.

Aedes intrudens Dyar is found south of the tree line in late spring (Wood et al. 1979). It has been recorded from all provinces (Steward and McWade 1960). The species was common in the eastern study area, but was not found in the western study area.

Aedes provocans is a forest species and is a southern species in Ontario (Wood et al. 1979), except for a single record from Great Slave Lake, Northwest Territories. We collected a single specimen in the eastern study area.

Aedes rempeli is one of the rarest Canadian species (Vockeroth 1954). However, Wood et al. (1979) suggested that this species may be widely but sparsely distributed in northern Ontario. We caught a single specimen along the Albany River about 150 km upstream from the James Bay coast.

Anopheles earlei Vargas is the most common species of this genus in Ontario. Our collections of this species in both study areas extend the known range.

Coquillettidia perturbans is common in southern Ontario (Wood et al. 1979). Jenkins et al. (1952) found that this species was very abundant in a spruce forest west of Cochrane, Ontario. In both study areas it was our most abundant species.

Culiseta impatiens is a northern species usually found in forested regions and has been recorded from Moose Factory (Steward and McWade 1960). Our single specimen came from the western study area, providing a westward extension of the known range.

Southward range extensions

Aedes nigripes is an arctic species whose range, according to Wood et al. (1979), did not extend southward into Ontario. However, one recent record exists from Polar Bear Provincial Park (Beresford 2011). One specimens was collected in the western study area in 2011, even farther south than Polar Bear Provincial Park.

Range gap infills

Aedes abserratus (Felt and Young) is an uncommon species in Ontario (Wood et al, 1979). Steward and McWade (1960) reported the species from Moose Factory. Beresford (2011) collected it in Polar Bear Provincial Park. Our collection of this species in both study areas fills the gap. *Aedes communis* (De Geer) is one of the most widely distributed species in the northern hemisphere. Beckel (1954) stated that this species was rarely collected in the Churchill area of Manitoba because it is non-biting in that area. In Ontario, records show it to be generally present and often abundant throughout the province. This species was well represented (9.4%) in our collections from the western study area, but less so (1%) in the eastern study area.

Aedes hexodontus Dyar has been collected in Churchill, Manitoba both as larvae (Vockeroth 1954) and as adults (Beckel 1954), and also from western Quebec and western Ontario (Wood et al, 1979). Our collection fills the gap.

Aedes impiger (Walker) is generally found in Nunavut and the Northwest Territories (Steward and McWade 1960). It has been caught in Ontario at Moose Factory and along the Albany River (Steward and McWade 1960) and in Manitoba at Churchill (Downes 1965). Our collections from our western study area fill a gap between Churchill and the James Bay coast in Quebec. Surprisingly, we did not find any in our eastern collections, which are close to James Bay.

Aedes pionips Dyar is found in the forests of central and northern Canada, and has been collected from Moose Factory, Ontario (Steward and McWade 1960) and Churchill, Manitoba (Beckel 1954). Not unexpectedly, our collections fill the gap.

Aedes punctor (Kirby) is a common species in Ontario and throughout Canada (Steward and McWade 1960). Records are from Moosonee (Jenkins and Knight 1952) and Churchill, Manitoba (Beckel 1954). Our collections are within the expected range but fill distributional gaps in northwestern Ontario.

Discussion

As expected we produced new distributional records, including both northward and southward range extensions, and filled gaps in known ranges. All of the species we collected are considered by CESCC (2011) to be secure (relatively widespread or abundant), except for five with undetermined status: *Aedes impiger*, *Ae. implicatus*, *Ae. pionips*, *Ae. rempeli* and *An. earlei*.

The rarefaction analysis, which standardizes across different sample sizes, indicates that the eastern region (2012) had slightly more species than the western region (2011). For example, in collections of 100 individuals we would only have been able to catch about 13 species in the east compared to 11 in west (Fig. 1). The lognormal analysis shows the same pattern, with 23.4 species predicted to be in the eastern region compared to 14.75 in the western region (Fig. 2). These analyses reveal that this difference in species richness may be a function of the different regions (e.g., habitats) rather than catch effort. The 2012 eastern study area collections were from sites with lower elevations (1–88 m) than the western sites (148–379 m). However, because these two regions were sampled in different years, we cannot attribute this difference to region alone.

From our survey of the range maps we expected to find up to 31 species. Fitting the lognormal distribution to our overall catch numbers, our expected number of species was 28, a good estimate of species richness of this region.

In fact, we found only 19 species and four of the species we did catch were not expected from the range map analysis: *Aedes nigripes, Ae. provocans, Ae. pullatus, Ae. rempeli.* This means that 16 species from the range map analysis were expected but not found, either due to our sampling methods, phenology, or habitat preferences. Of these, *Wyeomyia smithii* (Coquillett) is fully autogenous and has not been reported bloodfeeding; *Ae. diantaeus* Howard, Dyar and Knab is not found in coniferous forests; *Ae. spencerii* (Theobald) is not found in forest regions; *Ae. sticticus* (Meigen) is generally restricted to

floodwaters of rivers; *Culesita morsitans* (Theobald) and *Culex restuans* Theobald prefer to bloodfeed from birds; *Culex territans* Walker prefers reptiles and amphibians; *Culesita alaskaensis* (Ludlow) and *Ae. mercurator* Dyar are early spring species; *An. walkeri* (Theobald), *Ae. vexans* (Meigen) and *Ae. campestris* Dyar & Knab are primarily nocturnal biters. The remaining four of the expected species are rare, *Ae. riparius* Dyar & Knab, *Ae. flavescens* (Müller), *Ae. fitchii* (Felt & Young) and *Ae. decticus* (Howard, Dyar & Knab) (Wood et al. 1979).

All collection methods have inherent biases associated with them (Muirhead-Thomson 1991). Some important limitations to this survey are that collections occurred at randomly chosen sites (i.e., not selected for high probability of detecting mosquitoes) and using simple methods that were part of a larger diversity survey. The mosquito portion of that survey was limited by the logistics of available time and equipment at these remote sites. A collection effort that focused on targeting mosquitoes alone, within specific habitats, would likely have produced more of the expected species, and the use of CO_2 traps of CDC light traps would have produced far larger collections. Nevertheless, this study, despite its limitations, indicates that surveys undertaken in under-sampled regions can produce important baseline information that extends the previously known ranges.

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References

Beckel, W. E. 1954. The identification of adult female *Aedes* mosquitoes (Diptera, Culicidae) of the black-legged group taken in the field at Churchill, Manitoba. *Canadian Journal of Zoology* **32**: 324–330.

Beresford, D. 2011. Insect collections from Polar Bear Provincial Park, Ontario, with new records. *Journal of the Entomological Society of Ontario* **142**: 19–27.

CESCC 2011. Wild species 2010: the general status of species in Canada. National General Status Working Group. Canadian Endangered Species Conservation Council. Available online at: http://www.wildspecies.ca/wildspecies2010/downloads/wild-species-2010.pdf

Crins, W. J., Gray, P. A.,Uhlig, W. C. and Wester, M. C. 2009. The ecosystems of Ontario, Part 1. Ecozones and ecoregions. Report SIB TER IMA TR-01. Ontario Ministry of Natural Resources Inventory, Monitoring and Assessment Section. Peterborough, ON. 71 pp.

Darsie, R. F. and Ward, R. A. 2005. *Identification and geographical distribution of the mosquitoes of North America, North of Mexico.* University of Florida Press, Gainesville, FL. 400 pp.

Downes, J. A. 1965. Adaptations of insects in the arctic. *Annual Review of Entomology* **10**: 257–274.

FNSAP. 2010. *Science for a changing far north. The Report of the Far North Science Advisory Panel. A report submitted to the Ontario Ministry of Natural Resources.* Queen's Printer for Ontario, Toronto, ON. 141 pp.

Gillis, M. D., Omule, A. Y. and Brierley, T. 2005. Monitoring Canada's forests: the national forest inventory. *Forestry Chronicle* **81**: 214–221.

Jenkins, D. W. and Knight, K. L. 1952. Ecological survey of the mosquitoes of southern James Bay. *American Midland Naturalist* **47**: 456–468.

Ludwig J. A. and Reynolds, J. F. 1988. *Statistical Ecology: a primer on methods and computing.* John Wiley & Sons., New York, NY. 337 pp.

Muirhead-Thomson, R. C. 1991. *Trap responses of flying insects. The influence of trap design on capture efficiency.* Academic Press, San Diego, CA. 304 pp.

OMNR. 2012. Wildlife research: far North biodiversity. Ontario Ministry of Natural Resources. Available online at: http://www.mnr.gov.on.ca/en/Business/Wildlife/2ColumnSubPage/STDPROD_099955.html.

Steward, C. C. and McWade, J. W. 1960. The mosquitoes of Ontario (Diptera: Culicidae) with keys to the species and notes on distribution. *Proceedings of the Entomological Society of Ontario* **91**: 121–188.

Thielman, A. C., and Hunter, F. F. 2007. Photographic key to the adult female mosquitoes (Diptera: Culicidae) of Canada. *Canadian Journal of Arthropod Identification* 4, Available online at: http://www.ualberta.ca/bsc/ejournal/th_04/th_04.html, doi: 10.3752/cjai.2007.04

Wood, D. M., Dang, P. T. and Ellis, R. A. 1979. The mosquitoes of Canada (Diptera: Culicidae). *The Insects and Arachnids of Canada*, Part 6: Agriculture Canada. Publication 1686. 390 pp.

Vockeroth, J. R. 1954. Notes on the identities and distributions of *Aedes* species of northern Canada, with a key to the females (Diptera: Culicidae). *The Canadian Entomologist* **6**: 241–255.

WRBU. 2013. Traditional Mosquito Classification, July 2013. Walter Reed Biosystematics Unit. Available online at: http://www.wrbu.org/docs/mq_ClassificationTraditional201307.pdf.

TAXONOMY AND FAUNISTICS IN ONTARIO, 1952–2012: PUBLICATIONS IN THE "JOURNAL OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO"

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Publications on taxonomy and faunistics that appeared in the Journal of the Entomological Society of Ontario over a 60-year period beginning in 1952 are tabulated. These consist of 60 papers on taxonomy with a total of 700 species, including 125 new ones, described and/or keyed. Almost 100 papers on faunistics (lists, new distributions for North America or parts of North America) were published, with a total of 4700 species mentioned. A brief overview of taxonomy and faunistics as given in JESO volumes is provided.

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Introduction

Although the Entomological Society of Ontario (ESO) began in 1863, the first report was published in 1871 (covering the year 1870) and publication continued as Annual Reports up to 1958, then from 1959–2001 as the Proceedings of the Entomological Society of Ontario (PESO), and finally from 2002–present as the Journal of the Entomological Society of Ontario (JESO). Because the main goal of the Society at its inception was to publish research on pest insects the first volume was titled "First Annual Report of the Noxious Insects of the Province of Ontario" and subtitled "Prepared for the Agricultural and Arts, and Fruit Growers' Associations of Ontario, on Behalf of the Entomological Society of Canada." The first two articles in it were by the Rev. C. J. S. Bethune, entitled "Insects affecting the apple" and "Insects injurious to grape." The 61 magnificent black-and-white illustrations throughout Vol.1 and the 694 others in the next twelve volumes (illustrations summarized in detail in Vol. 13) stand as a testament to the careful attention to detail in the published papers.

Forward to the 1950s. Glen (1956) compiled a historical overview of entomology in Canada with contributions by different authors in 16 categories, one being Systematic Entomology by G. Holland. One category not treated by Glenn as a separate subdiscipline was faunistics, probably because most taxonomy and biology papers included information on insect distributions, even if it was for a single (usually pest) species, so "faunistics" was too vague to treat as a subdiscipline. To mark the 150th Anniversary of the Entomological Society of Ontario, papers in these two subdisciplines are compiled and briefly discussed

here. Only the past 60 years are treated, beginning with publication date 1953 (vol. 84) to provide a slight overlap with Holland (1956). The subdiscipline of taxonomy, "systematic entomology" of Holland, is complemented with a summary of papers on faunistics. The latter were written by both taxonomists and non-taxonomists, but the non-taxonomists relied heavily on taxonomists for specimen identifications. Over the past six decades both groups of entomologists added a lot of new information on insect distributions in Ontario or Canada. Because they do not include identification keys or taxon descriptions the papers on faunistics are summarized separately from those on taxonomy. Except for 19 papers on particular insect species, and five on insect associations with certain plant species, the faunistics papers exclude studies that detail the biology of single species, most of which are economically important as pests or biological control agents. Such papers are treated by P. Mason (this volume).

Taxonomy

Only about 1 taxonomy paper per year (60 in total) was published over the past 60 years (Table 1). These covered almost 700 species of which 125 were described as new. Twenty-five of the papers treated Ontario insects only. Most of them (47) included identification keys, usually to adults but sometimes to larvae or pupa. Somewhat surprisingly, 25 of the papers treated Diptera, 25 treated Hymenoptera but only 7 treated Coleoptera and 1 treated Lepidoptera. About 36 family group taxa and 50 genera were covered. A few papers were more general, treating Lepidoptera, Aculeata, and Symphyta. Two were on nomenclature and type specimens, respectively.

Although most publications in the Annual Reports over its first 80 years treated pest biology and control, the occasional paper foreshadowed the trend over the next 60 years towards more papers on taxonomy and faunistics of insects in general. Fletcher (1902), the founder of the Canadian National Collection of Insects, therefore began an Entomological Record. His aim was not to record facts connected to economic entomology—he called it "practical" entomology—but instead to publish information about other insects, including 1) a record of special rarities taken by collectors, with the various locations and dates, 2) the names of specialists who have devoted particular attention to some order, genus, species, or phases of taxonomic study, 3) the names of any books of note affecting entomology, or connected with any branch of it, which may have been published during the year. For the year, Fletcher summarized collecting thus "The season of 1901 in almost all parts of Canada has been characterized as 'poor' by nearly all collectors heard from." Most of Fletcher's publication gives a literature summary, lists of names and locations of collectors (36 for Lepidoptera, 10 for Coleoptera, and three each for Hymenoptera and Orthoptera), and 8 pages of "notes on captures" compiled by himself and, for Orthoptera, by E. M. Walker. The next year, Fletcher (1903) stated that he hoped at least some of the general collectors in all parts of the country might become specialists on particular taxa because they were urgently needed. He noted that the Lepidoptera and Coleoptera were always fairly well worked but specialists in the other orders were few. Fernald's (1916) paper on life zones in entomology and Felt's (1926) paper on insect distributions presage Walker's (1955) discussion on climate change, mentioned below. So right from the beginning of the 1900s there was interest and concern about taxonomy and distributions, particularly changing ones, of the insect fauna of Canada in general and Ontario in particular.

Faunistics

In 1961, C.G. MacNay's yearly article "A summary of the more important insect infestations and occurrences in Canada in 19xx" ceased to be published. Although this series of articles focused almost exclusively on pest insects from across Canada, other noteworthy species were occasionally mentioned. Thus, for 1950 (eighty-first Annual Report) one and a half lines were written on one species not considered a pest: "The noticeable scarcity of reports of this insect [the Painted Lady, *Vanessa cardui* L. (Lepidoptera: Nymphalidae)] contrasts with its widespread abundance in 1949". The rest of the 19-page article summarized the abundance of pest species under several subheadings: general feeders, field crop insects, vegetable insects, fruit insects, insects affecting greenhouse and ornamental plants, insects affecting man and domestic animals, household insects, stored product insects. All the other articles in the volume related to pesticides—it was, after all, shortly after start of the pesticide heyday/revolution. Similar examples occur in the 1951 Annual Report [one mention of a Mourning Cloak butterfly larva, *Nymphalis antiopa* (L.) (Lepidoptera: Nymphalidae)]. Almost invariably the record was in the context of damage to something of economic interest. Preventing damage to crops/animals/humans was seen as perhaps the most important task of entomology. In 1952, 150 years after Fletcher implemented his 'Entomological Record', a section on new records of insects in Canada was added. It included 17 species (5 in Ontario) recorded for the first time either for North America or for Canada or for a particular province. From 1966–1972, H. W. Goble and others published articles under the subheading "Review of infestations and other pests" but restricted their coverage to insects (and nematodes) in Ontario only. Vol. 104 (1973) was the last year such pest summaries were compiled. Thereafter, relatively more attention was paid to insects not of economic importance.

In 1954, a symposium on changing faunal ranges was held, in which various speakers discussed examples (in Lepidoptera, Ephemeroptera, Orthoptera, Hymenoptera, and Araneae) of Carolinian zone insects that showed evidence of a northward shift in distribution. Some crop pests already present in southern Ontario or new entries of insects into the Niagara Peninsula were included. Also exemplified were extensions of faunal ranges in the Prairie Provinces, species spreading with agriculture, species whose ranges fluctuate with climatic cycles, and species with annual northern migrations. Northern shifts in populations of some bird species in the Prairie Provinces and alien pest insect species introduced from abroad were also listed. The eminent E.M. Walker (1955), of odonatological fame, summarized things thus: "But looking back over the sixty odd years since I began to collect insects at De Grassi Point, Lake Simcoe, I have witnessed the gradual decrease in numbers of some species that were once common, until they vanished altogether, and I have seen other species, never known in that territory before, arrive there and in the course of time become firmly established. The species that disappeared were chiefly northern ones, whereas the newcomers were all from the south. This last statement suggests a changing climate that is becoming warmer. The problem, however, is not quite as simple as it seems." I take the Baker symposium, mentioned in Table 2, and Walker's comments as the main post-war starting point for the shift in emphasis on controlling pests to documenting and understanding the Ontario insect fauna in general, with emphasis on changing distributions. However, over 150 years previously Webster (1902) noted general

trends in insect movements around North America. Fernald (1916) and Felt (1926) also wrote about distributions and their significance, showing that within about 30 years since publication of the Annual Reports began entomologists were aware of the importance of tracking insect distributions.

Almost 100 papers on faunistics were published from 1953–2012 (Table 2), with a low of 8 papers in the 1950s to a high of 19 in the 1970s. Many of these are species lists, changes in distributions, or new provincial, country, or continent records. About 4700 arthropod (mostly insect) species in over 20 orders, especially Coleoptera, Diptera and Hymenoptera, are listed. A wide variety of faunistic topics are covered: insects on particular substrates, e.g., decaying mushrooms; in particular habitats, e.g., alvars; visitors to particular species of flowering plants, e.g., *Daucus carota* L. (*Apiaceae*); or natural enemies of particular, non-pest insects, e.g., *Bombus* spp. (Hymenoptera: Apidae). Almost every volume included at least one faunistics paper and a few volumes (104, 141, 142) as many as five. Most papers were restricted to insects of Ontario or parts of Ontario. Occasionally other provinces (Manitoba, Newfoundland, Nova Scotia, Quebec), or the USA or particular US states were treated. Sometimes all of Canada, the Nearctic region (usually America North of Mexico) or the entire New World (an abstract only) was covered.

Conclusions

Up to the 1950s the Annual Reports stressed pest biology and control, and many detailed papers appeared on their biology often accompanied by excellent line drawings. The Reports also included a smattering of more general papers discussing distributions (read faunistics) and taxonomy. Over the past six decades a greater diversity of papers has appeared, with relatively more emphasis on insects other than pests. On the whole, the Society's journal has provided a fair representation of entomological research in Ontario over most of the past 140 years. This has changed over the past decade. Fewer papers are published in JESO because of the greater number of competing, electronic journals, often with more specialized interests. JESO is therefore perhaps a less reliable tracker of entomological research in the province than previously. Nevertheless, JESO remains a good venue for publishing information on faunistics and taxonomy of Ontario insects.

TABLE 1. Publications on taxonomy in Volumes 82–140 (1952–2012) of the Entomological Society of Ontario.

Order	Family/other	Genus	Region	Key	# spp.	n. spp.	Author	Other details	Vol.	Year pub.
Araneae	Gnaphosidae	*Gnaphosa*	BC, USA (WA)	yes	2		Bennett et al.		137	2007
Coleoptera	Carabidae	*Coptodera*	New World	yes	43	12	Shpeley & Ball		124	1993
Coleoptera	Chrysomelidae	*Altica*	ne. N. Amer.	yes	2		LeSage	on *Vitaceae*	133	2003
Coleoptera	Dytiscidae		ON	yes	5		James	vernal pools	100	1970
Coleoptera	Monotomidae	*Monotoma*	Canada	yes	12	3	Bousquet & LaPlante		130	1999
Coleoptera	Pselaphinae		BC	yes	11		Chandler	Queen Charlotte Is.	131	2000
Coleoptera	Scarabaeidae	*Pedaridium*	Colombia	no	1	1	Gill & Vaz-de-Mello		133	2003
Coleoptera	Scolytinae	*Conophthorus*		no	1		De Groot	cuticular hydrocarbons	122	1991
Diptera	Anthomyiidae	*Hylemya*	ON	no	2		McLeod	crossing experiments	95	1965
Diptera	Camillidae	*Camilla*	Nearctic	yes	2		Kits et al.		143	2012
Diptera	Chamaemyiidae	*Pseudodinia*	New World	yes	17	5	Barber		116	1985
Diptera	Chironomidae	*Cricotopus*	ON, Salem Creek	yes	11	1	LeSage & Harrison		111	1981
Diptera	Clusiidae	*Sobarocephala*	Nearctic	yes	17	2	Lonsdale & Marshall		138	2007
Diptera	Culicidae		ON	yes	45		Steward and Wade		91	1961
Diptera	Empididae	*Wiedemannia*	USA (AZ)	no	1	1	Sinclair		137	2007
Diptera	Ephydridae	*Discomyia*	ON	yes	3		Buck et al.		137	2007
Diptera	Hybotidae	*Baeodromia*	New World	no	1		Cumming		137	2007
Diptera	Nycteribiidae	*Basilia*	Nearctic	yes	6		Peterson		90	1959
Diptera	Opomyzidae	*Geomyza*	Canada	no	2		Wheeler et al.		130	1999
Diptera	Phoridae	*Cyrtophorina*	Neotropical	yes	4	3	Brown		137	2007
Diptera	Simuliidae	*Cnephia, Simulium*	ON	yes	2	2	Wood		93	1963
Diptera	Simuliidae	*Prosimulium*		no	1		Peterson	nomenclature	95	1965
Diptera	Simuliidae		ON	yes	44		Davies et al.		92	1962
Diptera	Simuliidae		ON	yes	45				93	1963
Diptera	Sphaeroceridae	*Lotophila*	Holarctic	yes	5	2	Norrbom & Marshall		119	1989
Diptera	Sphaeroceridae	*Minilimosina*	New World	yes	21	21	Marshall		116	1985
Diptera	Sphaeroceridae	*Rachispoda*	New World	no	14	10	Wheeler	abstract	121	1990
Diptera	Sphaeroceridae	*Spelobia*	N. Amer.	no	1	1	Marshall		120	1989
Diptera	Sphaeroceridae		ON	yes	24	24	Marshall & Brown	decaying fungi, Guelph	115	1985
Diptera	Strongylophthalmyiidae	*Strongylophthalmyia*	Canada	yes	2	1	Barber		137	2007
Diptera	Tabanidae	*Atylotus*	e. N. Amer.	yes	10	3	Teskey		114	1984

TABLE 1 continued....

Order	Family/other	Genus	Region	Key	# spp.	n. spp.	Author	Other details	Vol.	Year pub.
Diptera	Tabanidae	*Merycomyia*	Nearctic	no	2		Pechuman		94	1964
Diptera	Tabanidae		ON	yes	87		Pechuman et al.	list of MB species	91	1961
Hymenoptera	Aculeata	*Cerceris, Chelostoma*	e. Canada	yes	23		Buck et al.	new records	136	2006
Hymenoptera	Apidae	*Ceratina*	ON	yes	3		Rehan & Richards	problematic spp.	139	2008
Hymenoptera	Apidae		ON	yes	17		Romankova	Epeolini	135	2006
Hymenoptera	Braconidae	*Euphoriella*	Nearctic	yes	10	7	Loan & New		102	1972
Hymenoptera	Braconidae	*Leiophron*	ON	yes	2	2	Loan	on *Lygus*	100	1970
Hymenoptera	Braconidae	*Trachagathis*	South America	yes	3	2	Sharkey		137	2007
Hymenoptera	Chalcidoidea, Cynipoidea			no			Sarazin	primary types in CNC	118	1988
Hymenoptera	Chrysididae	*Elampus*	Nearctic	yes	7	2	Huber & Pengelly		108	1980
Hymenoptera	Chrysididae	*Elampus*	Cuba, Puerto Rico	yes	2	2	Huber & Pengelly		108	1980
Hymenoptera	Colletidae	*Colletes*	ON	yes	16		Romankova		134	2004
Hymenoptera	Colletidae	*Hylaeus*	ON	yes	8		Romankova		138	2007
Hymenoptera	Colletidae	*Hylaeus*	Canada	yes	2		Sheffield et al.	non-native bee list	142	2011
Hymenoptera	Crabronidae	*Hoplisoides*	Canada	yes	8		Buck		137	2007
Hymenoptera	Diprionidae	*Neodiprion*	ON	no	6		West et al.	serology	89	1958
Hymenoptera	Eucharitidae		Nearctic	yes	16	5	Heraty		116	1985
Hymenoptera	Megachilidae		ON	yes	5		Romankova	Anthidiini	134	2004
Hymenoptera	Mymaridae	*Anaphes*	Nearctic	yes	9		Huber	*fuscipennis* group	123	1992
Hymenoptera	Mymaridae	*Anaphes*	Nearctic	yes	13		Huber	*crassicornis* group	135	2006
Hymenoptera	Mymaridae	*Camptoptera*	World	yes		2	Huber & Lin	key to genera	130	1999
Hymenoptera	Mymaridae	*Eustochus*	World	yes	8	4	Huber & Baquero		138	2007
Hymenoptera	Mymaridae	*Ooctonus*	Nearctic	yes	14	5	Huber		143	2012
Hymenoptera	Mymaridae	*Stephanodes*	World	yes	5	1	Huber & Fidalgo		128	1997
Hymenoptera	Perilampidae	*Jambiya*	Israel, Yemen	no	1	1	Heraty & Darling		138	2007
Hymenoptera	Symphyta		ON	yes	23		Lindquist & Miller	on birch, alder	100	1970
Hymenoptera	Symphyta		ON	yes	14		Lindquist & Miller	on spruce, balsam fir	102	1972
Isopoda			ON	yes	18		Belaoussof et al.		129	1998
Lepidoptera			ON	yes	19		Lindquist & Miller	on alder	100	1970

TABLE 2. Publications on faunistics in Volumes 82–140 (1952–2012) of the Entomological Society of Ontario.

Vol.	Publ. year	Author(s)	Area	Locality	Key words	Order	Family	Genus	# spp.	Species
82	1952	Robinson	MB		predators of		Tetranychidae		23	
83	1952	Judd	ON	London	reared from galls	Diptera	Cecidomyiidae	*Rabdophaga*	16	*strobiloides* Walsh
84	1952	Fox & Stirrett	Can.		tobacco pests, catalogue				ca. 70	
84	1953	Pengelly	ON	southern	alfalfa pollination	Hymenoptera	Apoidea		ca. 25	
86	1955	Baker (symposium)	ON		changing faunal ranges					
87	1957	Miller	ON		pest range changes				6	
87	1957	Pechuman	Can.		new for country	Diptera	Tabanidae		12	
87	1957	Pengelly	ON	Bruce Co.	records	Araneae		*Latrodectus*		*mactans* (Fabricius)
88	1958	Hicks	ON		new for province	Coleoptera	Curculionidae	*Brachyrhinus*		*raucus* (Fabricius)
91	1961	Atwood	ON		list, review	Hymenoptera	Diprionidae		16	
91	1961	Teskey	ON		list	Diptera	Hypodermatinae		2	
92	1962	Knerrer & Atwood	ON		list	Hymenoptera	Halictidae (non-parasitic)		59	
93	1963	Benedict	ON	Windsor area	list	Diptera	Culicidae		17	
93	1963	Peterson	USA, Mex.		records	Diptera	Nycteribiidae		5	
94	1964	Knerrer & Atwood	ON		list	Hymenoptera	Andrenidae		70	
95	1965	Graves	ON		distribution	Coleoptera	Cicindellidae		13	
96	1966	Belton & Galloway	ON	Belleville area	phenology	Diptera	Culicidae		24	
97	1967	Vickery & Kevan	ON		list	Orthopteroidea s.l.			127	
97	1967	Judd	ON	London	pond-emerging insects				ca. 60	
97	1967	Knerrer & Atwood	ON	Toronto area	inquilines, parasitoids	Hymenoptera	social Halictidae		6	
98	1968	Riotte	ON	Halton Co.	new for province	Lepidoptera	Pieridae	*Pieris*		*virginiensis* Edwards
98	1968	McClanahan et al.	ON	Essex Co.	new for province	Coleoptera	Chrysomelidae	*Oulema*		*melanopus* (L.)

TABLE 2 continued...

Vol.	Publ. year	Author(s)	Area	Locality	Key words	Order	Family	Genus	# spp.	Species
98	1968	Judd	ON	Byron Bog	list	Odonata			22	
98	1968	Judd	ON	Byron Bog	list	Coleoptera	Dytiscidae, Hydrophilidae		26	
99	1969	Judd	ON	Byron Bog	insects visiting		*Asteraceae*	*Eupatorium*	43	*perfoliatum* L.
99	1969	Munroe	ON		distribution, postglacial origin					
100	1970	Judd	ON	southern	insects visiting		*Apiaceae*	*Daucus*	66	*carota* L.
100	1970	James et al.	ON	southeastern	list	Diptera	Culicidae, Chaoboridae		40	
101	1971	Judd	ON	Byron Bog	insects visiting		*Asteraceae*	*Taraxacum*	24	*officinale* Weber
101	1971	Dondale	ON	Belleville area	list, mown field	Araneae			150	
101	1971	Brower & Brower	ME		reared from pitcher plants	Lepidoptera			3	
102	1972	New & Loan	ON	Belleville area	list	Psocoptera			24	
102	1972	Judd	ON	Owen Sound	pollinating		Vespidae	*Epipactis*	4	*helleborine* (L.)
102	1972	Dutchback et al.	ON	Thunder Bay	new record for province	Coleoptera	Carabidae	*Trechus*		*crassiscapus* Lindroth
103	1973	Hagley & Hikichi	ON		unsprayed apple orchards, major pests	Lepidoptera, Diptera Coleoptera			20	
104	1974	Foott	ON	Essex Co.	corn fields	Coleoptera	Coccinellidae		6	
104	1974	MacFarlane	N.Am.		arthropod predators of	Hymenoptera	Apidae	*Bombus*	ca. 30	
104	1974	Watson	ON	Sudbury	new for province	Diptera	Cecidomyiidae	*Dasineura*		*aceris* (Shimer)
104	1974	Freitag & Ryder	ON	Granite I., Black Bay	arthropods in gull nests				ca. 30	
104	1974	Larochelle	QC	Anticosti I.		Coleoptera	Carabidae		83	
105	1975	Hagley & Hikichi	ON		predators in unsprayed apple orchards	Insecta, Acari			ca. 110	

TABLE 2 continued...

Vol.	Publ. year	Author(s)	Area	Locality	Key words	Order	Family	Genus	# spp.	Species
105	1975	Vickery & Kerr	ON		list, additions	Grylloptera			26	
106	1976	Morris	NL		butterfly list	Lepidoptera			61	
107	1977	Judd	ON	Haldimand Co.	list	Isopoda			7	
108	1978	Judd	ON	Haldimand Co.	list	Opiliones			7	
109	1979	Tomlin & Nagy	ON	southwestern	new for province	Diplura	Japygidae		1	
110	1980	Broadbent & Tomlin	ON	Guelph, London	list, corn field, pasture	Acari			76	
110	1980	Tyler & Ellis	ON	Elora	corn fields	Coleoptera	Carabidae		23	
112	1982	Tomlin	ON	southern	new for province	Protura			>2	
114	1984	Judd	ON	Haldimand Co.	insects visiting		*Dipsacaceae*	*Dipsacus*	41	*fullonum* L.
115	1985	Brown & Marshall	ON	Guelph, London	list, in decaying fungi	Diptera	Phoridae		36	
117	1987	Sinclair & Marshall	ON	southern	madicolous habitats				76	
117	1987	Pendreigh & Marshall	ON	Algonquin Prov. Pk.	sphagnum bog	Diptera	Sphaeroceridae		ca. 23	
118	1988	Williams & Williams	Can.		freshwater springs	Trichoptera			ca. 64	
118	1988	Peck & Kaulbars	USA		distribution, bionomics	Coleoptera	Silphidae		27	
118	1988	Vickery & Scudder	Can.		list	Orthopteroidea s.l.			300	
119	1989	Rothman & Lorne	ON	Toronto	landfill	Acari	Phytoseeidae		11	
120	1989	Nystrom & Evans	ON	Newmarket	new for North America	Hymenoptera	Tenthredinidae	*Scolioneura*		*betuleti* (Klug)
121	1990	Swann	ON	St. Joseph I.		Diptera	Sphaeroceridae		2	
121	1990	Wheeler	New World			Diptera	Sphaeroceridae		10	
122	1991	Smith	Can.	Guelph	new for Canada	Hymenoptera	Megachilidae	*Megachile*		*manicatum* (L.)
122	1991	Marshall	Can.		collections to track faunal change					

TABLE 2 continued...

Vol.	Publ. year	Author(s)	Area	Locality	Key words	Order	Family	Genus	# spp.	Species
125	1994	Harper & Ricker	ON		distribution	Plecoptera			78	
126	1995	Skidmore	Can., AK		list	Collembola			412	
126	1995	Myles	ON		new records	Isoptera			3	
127	1996	Bright	ON	Niagara area	parasitoids/predators	Coleoptera	Scolytinae	*Tomicus*	11	*piniperda* (L.)
127	1996	Catling	ON	southern, eastern	northward expansion	Odonata	Coenagrionidae	*Enallagma*		*civile* (Hagen)
128	1997	Skevington & Carmichael	ON	Lampton Co.	list	Odonata			66	
129	1998	Suger et al.	ON	southern	oak savannah	Hymenoptera	Symphyta, Aculeata		145	
129	1998	McCafferty & Randolph	Can.		list	Ephemeroptera			321	
131	2000	Paquin & Lesage	QC	Gaspésie Park	list	Araneae			105	
132	2001	McCorquodale	ON		new records	Coleoptera	Cerambycidae		14	
132	2001	Bouchard et al.	ON		Auchenorhyncha in alvars	Hemiptera			18	
132	2001	Paquin & Dupérré	QC	western	boreal forest	Coleoptera			757	
134	2004	Buck	ON		list	Hymenoptera	Sphecidae, s.l.		278	
134	2004	Paiero et al.	Can.		new for country	Hemiptera			39	
134	2004	Godsoe	ON		extirpation in	Hymenoptera	Pompilidae	*Ceropales*		*bipunctata* Say
134	2004	Paiero & Buck	Can.		new for Canada	Hymenoptera	Apoidea		4	
135	2006	Marshall et al.	Can.		new records/distributions	Orthoptera			16	
136	2006	Bouchard et al.	ON		alvars	Coleoptera	Carabidae		142	
137	2007	Galloway	MB		parasites of Caprimulgidae	Acari, Phthiraptera			2	

TABLE 2 continued...

Vol.	Publ. year	Author(s)	Area	Locality	Key words	Order	Family	Genus	# spp.	Species
137	2007	Turnock et al.	MB		canola fields	Hymenoptera	Apidae	*Bombus*	15	
138	2007	McCorquodale et al.	ON		species decline, loss	Coleoptera	Cerambycidae		11	
139	2008	Paquin	QC		additions	Araneae			8	
140	2009	Cutler & Rogers	NS		new for province	Coleoptera	Scarabaeidae	*Maladera*		*castanea* (Arrow)
140	2009	Skevington & Goolsby	AZ		new host records	Diptera	Pipunculidae		2	
141	2010	Vickruck et al.	ON	southern	natural enemies	Hymenoptera	Apidae	*Ceratina*	8	
141	2010	Catling et al.	ON		alvars	Orthoptera			89	
						Coleoptera, Araneae				
141	2010	Colla & Dumesh	ON		phenology	Hymenoptera	Apidae	*Bombus*	18	
141	2010	Procter et al.	ON	south, central	hardwood forests	Coleoptera	Curculionidae		26	
141	2010	Sheffield et al.	ON	St. Catharines	new for province	Hymenoptera	Apidae	*Megachile*		*ericetorum* Lepeletier
142	2011	Douglas	N. Am.		new records	Coleoptera	Elateridae		16	
142	2011	Beresford	ON	Polar Bear Prov. Pk.	insects, list				44	
142	2011	Fogain & Graff	Can.		new for country	Hemiptera	Pentatomidae	*Hyalomorpha*		*halys* (Stål)
142	2011	McAlpine & Olden	ON	Renfrew Co.	new for province	Isopoda	Trichoniscidae	*Hyloniscus*		*riparius* (Koch)
142	2011	Sheffield & Williams	AK	Attu I.	new for North America	Hymenoptera	Apidae	*Bombus*		*distinguendus* Morawitz
143	2012	Denomme-Brown & Otis	ON	southern	distribution	Lepidoptera	Lycaenidae	*Callophrys*		*gryneus* (Hübner)
143	2012	Huber & Read	ON	Niagara on the Lake	new for province	Hymenoptera	Cynipidae	*Dryocosmus*		*kuriphilus* Yasumatsu

References

Felt, E. P. 1926. The distribution of insects and the significance of extralimital data. *Fifty-sixth Annual Report of the Entomological Society of Ontario, 1925.* Pp. 44–47.

Fernald, H. T. 1916. Life zones in entomology and their relations to crops. Forty-sixth *Annual Report of the Entomological Society of Ontario, 1915.* Pp. 87–92.

Fletcher, J. 1902. Entomological record, 1901. *Thirty-second Annual Report of the Entomological Society of Ontario, 1901.* Pp. 99–109.

Fletcher, J. 1903. Entomological record, 1902. *Thirty-third Annual Report of the Entomological Society of Ontario, 1902.* Pp. 97–101.

Glenn, R. 1956. Entomology in Canada up to 1956: a review of developments and accomplishments. *The Canadian Entomologist* **88**: 290–371.

Holland, G. P. 1956. Systematic Entomology. Pp. 300–304 *in* Glenn, R. (compiler), Entomology in Canada up to 1956: a review of developments and accomplishments. *The Canadian Entomologist* **88**: 290–371.

Walker, E. M. 1955. Summary of symposium. Pp. 37–38 *in* Baker, A. W. (co-ordinator), Symposium II. Changing faunal ranges. *Annual Report of the Entomological Society of Ontario* **86**: 23–39.

Webster, F. M. 1902. The trend of insect diffusion in North America. *Thirty-second Annual Report of the Entomological Society of Ontario, 1902.* Pp. 63–67.

BIOLOGICAL CONTROL IN ONTARIO 1952–2012: A SUMMARY OF PUBLICATIONS IN THE "JOURNAL OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO"

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Introduction

Biological control involves the manipulation of natural enemies to regulate populations of pest species. This biologically based approach is key to the successful management of pest species, and requires a sound understanding of the pest, its associated organisms and their interactions. A first step is to understand the biology of a target species which allows determination of such things as number of generations per growing season, life stages that cause damage, and life stages that are appropriate for control. Knowledge of the natural enemy community associated with a pest species will provide an indication of the potential for biological control to suppress and maintain populations below economically damaging levels. In Ontario, biological control began in 1882 when W. Saunders imported *Trichogramma minutum* Riley (Hymenoptera: Trichogrammatidae) from New York state for release in Ontario gardens to control the Imported Currantworm *Nematus ribesii* (Scopoli) (Hymenoptera: Tenthredinidae) (Glen 1962).

The present compilation summarizes the biological control contributions published in the *Annual Report of the Entomological Society of Ontario* / *Proceedings of the Entomological Society of Ontario* / *Journal of the Entomological Society of Ontario* (together, JESO) from 1952–2012 as part of the commemorative activities to celebrate the 150th anniversary of the Entomological Societies of Canada and Ontario. Although most cover work in Ontario, several (e.g., James 1952; Maxwell and Morgan 1952; Robinson 1952), address studies in other regions. Glen (1956) summarized work in entomology, including biological control in Canada to 1956 and this should be consulted for information on studies prior to 1952. It should be noted that studies published in JESO document only a portion of the work on each species. More comprehensive accounts can be found in the *Biological Control Programmes in Canada* series (McLeod et al. 1962; Kelleher et al. 1971; Kelleher and Hulme 1984; Mason and Huber 2002; Mason and Gillespie 2013).

Several contributions provide general summaries of the knowledge at the time of their publication. Chant (1957) provided an overview of papers relevant to biological control

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presented at the 10th International Congress of Entomology. Cameron (1952) conducted a review of diseases of insects to 1951 and Cameron (1969) reviewed the problems and prospects in the use of pathogens for insect control. Putnam (1963) reviewed the biology and management of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae). Wallace and Sullivan (1985) reviewed the status of the white pine weevil, *Pissodes strobi* (Peck) (Coleoptera: Curculionidae).

Proverbs (1962) and Van Whervin & Wilde (1970) reported on sterile insect release for control of codling moth, however this technique falls outside of the definition used in this summary (i.e., manipulation of natural enemies) as does work with plant extracts such as that reported for neem, *Azadirachta indica* A. de Jussieu (*Meliaceae*), by Lyons et al. (1996) on the Pine False Webworm, *Acantholyda erythrocephala* (L.) (Hymenoptera: Pamphiliidae) and by Li (2000) against Balsam Fir Sawfly, *Neodiprion abietis* (Harris) (Hymenoptera: Diprionidae).

In Ontario, more than 75 species have been the subject of studies in which associated natural enemies have been documented. Introduction of exotic natural enemy species were implemented for 12 invasive alien arthropods and five exotic weeds. The contributions published in JESO on these species are varied but can be divided into broad categories, Pest Life History and Natural Enemy Complexes, General Studies of Natural Enemy Communities, Natural Enemy Biology, Classical Biological Control of Weeds, Classical Biological Control of Arthropods, and Inundative Biological Control using Pathogens. Fundamental to successful biological is correct identification of their natural enemies so taxonomic studies treating relevant species are therefore also summarized under Natural Enemy Taxonomy. The approach used here summarizes, under each of the categories mentioned above, the findings published in JESO for each species studied. The 140 full length scientific papers, scientific notes and abstracts include those that identified natural enemies (arthropods and pathogens) associated with a host species and those reporting on aspects of the biology of natural enemies of pest and beneficial species. A list of the updated names of natural enemies and known hosts published in JESO from 1952–2012 is provided in the Appendix.

1. Pest Life History and Natural Enemy Complexes

The development of intensive agriculture brings with it a host of species that exploit a food source that, grown in large uniform plots, provides one of the optimum conditions that contributes to exponential population increases. Fundamental to implementing successful biological control is understanding the biology of target species well and identifying which natural enemies already present in the system attack the various life stages of the host. In Ontario, numerous studies have documented the natural enemies of native and non-native species, usually in response to outbreaks in particular crops or regions. In addition to greater knowledge of pest biologies these studies have increased knowledge of their natural enemies present in Ontario. A summary of the findings published in JESO for each species follows.

Apple Maggot, *Rhagoletis pomonella* (Walsh) (Diptera: Tephritidae) is a native species that occurs in Ontario and Quebec (Hoffmeister 2002). Monteith (1977; 1978) studied potential predators of apple maggot, e.g., the sowbug, *Porcellio laevis* Latreille (Isopoda: Oniscidae), centipede, *Lithobius forficatus* (L.) (Lithobiomorpha: Lithobiidae), earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae), and beetles, including

Calosoma calidum (Fabricius), *Harpalus pensylvanicus* DeGeer (Coleoptera: Carabidae), and *Staphylinus badipes* LeConte (Coleoptera: Staphylinidae), which effectively attacked and consumed apple maggot larvae. Millipedes, *Trachelipus rathkei* (Koch) (Polydesmida: Paradoxosomatidae), attacked puparia. Monteith (1978) also reported on apple maggot parasitoids, including *Diachasma mellea* (Gahan), *D. lectus* Gahan, *D. lectoides* (Gahan), *D. alloeum* (Muesebeck) and *D. ferrugineum* (Gahan) (Hymenoptera: Braconidae). Although these parasitoid species survived in wild habitats with apple and *Crataegus* spp. (*Rosaceae*), their numbers were not sufficient to migrate into and reduce apple maggot populations in managed orchards where even low numbers of this pest could not be tolerated. Poinar et al. (1978) isolated the potential pathogens, *Pseudomonas aeruginosa* (Schroeter) Migula, *Bacillus cereus* Frankland and Frankland (Bacilliaceae), and *Streptococcus* sp. (Streptococcaceae) from larvae and puparia. A nematode, *Neoaplectana* sp. (Rhabditida: Steinernematidae) was also associated with puparia. The study suggested that natural infestation by microorganisms might play an important role in regulating apple maggot populations.

Armyworm, *Mythimna unipuncta* (Haworth) (Lepidoptera: Noctuidae), a Nearctic species, was studied by Goble (1965) during an outbreak in 1964. The nuclear polyhedrosis virus *Betabaculovirus* sp. (*Baculoviridae*) killed 35% of larvae. Parasitoids caused an additional 25% mortality, particularly two *Apanteles* spp. (Hymenoptera: Braconidae) and other Hymenoptera (20% and 3.3% mortality, respectively) as well as Diptera (1%). *Winthemia* sp. (Diptera: Tachinidae) was abundant at one site and birds consumed large numbers of larvae. It was concluded that overall, natural control was of such magnitude that the population was likely to crash without intervention.

Birch Leaf Edgeminer, *Scolioneura betuleti* (Klug) (Hymenoptera: Tenthredinidae), first discovered in Ontario in 1983 near Newmarket, represented a first record for North America (Nystrom and Evans 1989). They reported 12% parasitism by three larval parasitoids, *Chrysocharis laricinellae* (Ratzeburg), *Pnigalio minio* (Walker), and *Zagrammosoma multilineatum* (Ashmead) (Hymenoptera: Eulophidae).

Black Army Cutworm, *Actebia fennica* (Tauscher) (Lepidoptera: Noctuidae), a Holarctic species, was studied in black spruce plantations in Newfoundland by West (1992). Parasitism levels of up to 60% were documented. *Tachinomyia panaetius* (Walker) (Diptera: Tachinidae), and *Campoletis* sp. (Hymenoptera: Ichneumonidae) were reared from larvae. *Gonia* sp. (Diptera: Tachinidae), and *Enicospilus* sp., *Ichneumon creperus* Cresson, and *Arenetra rufipes* Cresson (Hymenoptera: Ichneumonidae) were reared from pupae. The nematode, *Steinernema feltiae* (Filipjev) (Rhabiditida: Steinernematidae) also showed promise as a potential control agent. West (1992) recommended that since only *I. creperus* was known to occur in British Columbia, where black army cutworm was also a problem, relocation of the other spp. may be useful for biological control of *A. fennica* in that province.

Cabbage Looper, *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), is an annual migrant from the southern USA. Harcourt (1963) determined that *T. ni* was significantly impacted by *Copidosoma truncatellum* (Dalman) (Hymenoptera: Encyrtidae) but less so by the polyphagous *Itoplectis conquisitor* (Say), *Stenichneumon culpator cincticornis* (Cresson) (Hymenoptera: Ichneumonidae) and *Compsilura concinnata* (Meigen) (Diptera: Tachinidae). Polyhedral virus disease frequently killed larvae. Murillo et al. (2012) studied

the larval parasitoids of *T. ni* in field tomatoes in southwestern Ontario. Nine primary parasitoids were reared from *T. ni* larvae, including an unidentified Tachinidae, *Exeristes comstockii* (Cresson) (Hymenoptera: Ichneumonidae), *Copidosoma floridanum* (Ashmead) (Hymenoptera: Encyrtidae), *Cotesia marginiventris* (Cresson), *C. plathypenae* (Muesebeck), *Meteorus* sp., and *Microplitis alaskensis* (Ashmead), one unidentified species (Hymenoptera: Braconidae), and *Euplectrus* sp. (Hymenoptera: Eulophidae). One hyperparasitoid, *Trichomalopsis viridescens* (Walsh) (Hymenoptera: Pteromalidae) was reared from *E. comstockii*, the most abundant parasitoid (17.6% and 39.2% parasitism levels in 2005 and 2006, respectively). Although common parasitoids of *T. ni* in other parts of North America, *C. floridanum* and *C. marginiventris* occurred in <2% of the host populations in Ontario. The association of *C. plathypenae* with *T. ni* was a new host record.

Corn Aphid, *Rhopalosiphum maidis* (Fitch) (Hemiptera: Aphididae), is an important introduced pest of corn. Foot (1974) studied the Coccinellidae (Coleoptera) community in corn fields in southwestern Ontario. He found that *Hippodamia convergens* Guérin-Méneville, *H. tredecimpunctata tibilais* (Say), and *Coleomegilla maculata lengi* Timberlake were the most abundant species. *Adalia bipunctata* (L.), *Cycloneda sanguinea* (L.), *H. parenthesis* (Say), and *Coccinella transversoguttata* Faldermann were present but either not abundant or did not occur in all years. It was concluded that coccinellid numbers overall were insufficient to control corn aphid as high populations of beetles occurred only after aphid populations peaked and had damaged the crop.

Diamondback Moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), first found in the Ottawa area in 1854, is a global pest of cole crops. Harcourt (1963) determined that native parasitoids were a major mortality factor, the most important being the larval-prepupal parasitoid *Diadegma insulare* (Cresson) (33%), the prepupal-pupal parasitoid *Diadromus subtilicornis* (Gravenhorst) (21%) (Hymenoptera: Ichneumonidae), and the larval parasitoid *Microplitis plutellae* (Muesebeck) (Hymenoptera: Braconidae). Several species were of lesser significance including, *Oomyzus sokolowskii* (Kurdjumov) (Hymenoptera: Eulophidae), *Conura albifrons* (Walsh) (Hymenoptera: Chalcididae), *Gelis tenellus* (Say), *Campoletis* sp. (Hymenoptera: Ichneumonidae), *Dibrachys microgastri* (Bouché), *Pteromalus* sp. near *phycidis* Ashmead, and *Trichomalopsis viridescens*. According to Harcourt (1963) predators and diseases did not significantly affect *P. xylostella* populations.

European Red Mite, *Panonychus ulmi* (Koch) (Trombidiformes: Tetranychidae), a non-native species, is a serious pest of fruit crops in Canada (Thistlewood et al. 2013). Herbert (1953) studied the predacious phytoseid mites associated with European red mite in orchards. More than nine species were collected, including *Typhlodromus tilae* Oudemans, *T. rhenanus* (Oudemans), *T. pomi* (Parrot, Hodgkiss and Shoene), *Neoseiulus fallacis* (Garman), *T. conspicuous* var. *herbertae* Nesbitt, *T. finlandicus* (Oudemans), *T. masseei* (Nesbitt), *Phytoseius macropilis* (Banks) and *Amblyseius* spp. (Trombidiformes: Phytoseiidae). Abundance and species compositions varied among locations and years. Populations were denser in the centre of orchards in spring and early summer but increased at the periphery in midsummer, then decreased as autumn approached. Cadogan and Laing (1982) surveyed apple orchards in southern Ontario for the European red mite and its predator *Balaustium putnami* Smiley (Trombidiformes: Erythraeidae). Two distinct generations of *B. putnami* occurred, the 1st generation having an abundance of larvae and the 2nd generation being dominated by nymphs and adults (motile stages). *Balaustium putnami* coexisted with

Phytoseiidae and Stigmaeiidae and fed on both *P. ulmi* and the twospotted spider mite, *Tetranychus urticae* Koch (Trombidiformes: Tetranychidae). *Balaustium putnami* was also present in orchards with low volume pesticide application regimes suggesting that spray regimes and schedules could be designed to preserve natural enemies.

European Skipper, *Thymelicus lineola* (Ochsenheimer) (Lepidoptera: Hesperiidae), was first collected in 1910 near London, Ontario (Pengelly 1961). He studied its biology near Bradford, Ontario in 1958. Several native parasitoid species were recovered. Parasitism of pupae was low at 4.9%, mainly by *Itoplectis conquisitor*. Also reared from pupae were *Pimpla pedalis* Cresson and *Camposcopus* sp. (Hymenoptera: Ichneumonidae). Larval parasitoids included *Meteorus hyphantriae* Riley, *Rogas* sp. and *Casinaria* sp. (Hymenoptera: Braconidae). The hyperparasitoid *Gelis* sp. (Hymenoptera: Ichneumonidae) was reared from *M. hyphantriae*. Several Tachinidae were also reared from larvae.

Forest Tent Caterpillar, *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae), a cyclical pest of deciduous trees, was studied by Harmsen and Rose (1984). They documented differential mortality in wet low-lying and dry higher-ground habitats. Parasitism by *Aleiodes malacosomatos* (Mason) (Hymenoptera: Braconidae) and *Phobocampe clisiocampae* (Weed) (Hymenoptera: Ichneumonidae) and predation by unspecified species were lower in the low-lying areas, likely due to limited accessibility of appropriate sites for pupation and the greater accessibility for predators offered by drier habitats.

Goldenrod Gall Moth, *Epiblema scudderiana* (Clemens) (Lepidoptera: Tortricidae) was the subject of a parasitoid survey by Laing and Heraty (1982) who found the primary parasitoids *Apanteles cacoeciae* Riley, *Macrocentrus pallisteri* DeGant, *Bassus binominatus* (Muesebeck) (Hymenoptera: Braconidae) and *Scambus pterophori* Ashmead (Hymenoptera: Ichneumonidae), and the hyperparasitoid *Perilampus fulvicornis* Ashmead (Hymenoptera: Perilampidae), which attacked all the primary parasitoids. Overall parasitism was 32.4% in 1978–1979, 64.4% in1979–1980, and 76.6% in 1980–1981. Parasitism by *M. pallisteri* was the major factor influencing the large annual fluctuations (19.4% in 1978–79, 57.5% in 1979–1980, and 67.5% in 1980–81) in *E. scudderiana* populations. *Perilampus fulvicornis* appeared to be an important regulator of *M. pallisteri*, preventing it from drastically reducing *E. scudderiana* populations.

Horse and deer flies (Diptera: Tabanidae) were the subject of natural enemy surveys in Churchill, Manitoba by James (1952). The chalcid larval-pupal parasitoid *Diglochis occidentalis* (Ashmead) (Hymenoptera: Pteromalidae) was found to parasitize 13.9% of *Tabanus* spp., including *T. affinis* Kirby and the *T. frontalis-septentrionalis* complex, and 20.8% of *Chrysops* spp., including *C. frigidus* Osten-Sacken, and *C. furcatus* Walker. Numbers of *D. occidentalis* that emerged from *Tabanus* spp. averaged 45.5 while the smaller *Chrysops* spp. yielded an average of 16.1.

McDaniel Spider Mite, *Tetranychus mcdanieli* McGregor, the **Apple Mite**, *Tetranychus pacificus* McGregor, and the **Clover Mite**, *Bryobia praetiosa* Koch (Trombidiformes: Tetranychidae) in Manitoba were the subject of a survey by Robinson (1952) to document their predators. The following species were collected: *Stethocorus punctum* (LeConte), *Adalia punctata* (L.) (Coleoptera: Coccinellidae), *Stilbus probatus* Casey (Coleoptera: Phalacrididae), *Orius insidiosus* (Say), *Anthocoris musculus* (Say) (Hemiptera: Anthocoridae), *Diaphnidia pellucida* Uhler, *Hyaloides harti* Knight, *H. vitripennis* (Say),

Plagiognathus obscurus (Uhler) (Hemiptera: Miridae), *Nabis ferus* (L.) (Hemiptera: Nabidae), *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae), *Aeolothrips melaleucus* Haliday (Thysanoptera: Aelothripidae), *Feltiella* sp. (Diptera: Cecidomyiidae), *Toxomerus geminatus* (Say) (Diptera: Syrphidae), *Chrysopa carnea* (Stephens), *C. chi* Fitch (Neuroptera: Chrysopidae), *Hemerobius simulans* Walker, *H. stigmaterus* Fitch (Neuroptera: Hemerobiidae), *Typhlodromus fallacis* (Garman), *T. longipilus* Nesbit (Megostigmata: Phytoseiidae), and *Anystis agilis* Banks (Trombidiformes: Anystidae).

Northern Corn Rootworm, *Diabrotica barberi* Smith and Lawrence (Coleoptera: Chysomelidae), native to North America, is a minor pest in Ontario. Tyler and Ellis (1980) studied the importance of ground beetles as its predators. Among the 26 species collected, *Pterostichus melanarius* (Illiger), *Clivina fossor* (L.), *Agonum muelleri* (Herbst), *Bembidion quadrimaculatum oppositum* Say, *Poecilus lucublandus* (Say), and *Harpalus affinis* (Schrank) (Coleoptera: Carabidae) were most numerous. Radioactive labelling trials indicated that carabids were probably more important as larval than egg predators.

Obliquebanded Leafroller, *Choristoneura rosaceana* (Harris), the **Eyespotted Bud Moth**, *Spilonota ocellana* (Dennis and Schiffermüller), and the **Pale Apple Budworm**, *Pseudexentera mali* Freeman (Lepidoptera: Tortricidae) all native species, were present at all sites surveyed by Hagley and Barber (1992). Although parasitism levels in unmanaged apple orchards in southern Ontario were low (4–10%), parasitoids reared included 24 species of Hymenoptera and two species of Diptera. *Itoplectis conquisitor* was the most frequently reared parasitoid from obliquebanded leafroller and pale apple budworm and *Bassus dimidiator* (Nees) (Hymenoptera: Braconidae) was most frequently reared from eyespotted bud moth. The first records of *Colpoclypeus florus* (Walker) (Hymenoptera: Eulophidae) from obliquebanded leafroller and eyespotted bud moth were reported. *Colpoclypeus florus* had earlier been introduced from Europe to control the redbanded leafroller (see below). Highest parasitism levels were found in *Coleophora* spp. (Lepidopera: Coleophoridae) (30.2%) and *Sparganothis* spp. (Lepidoptera: Tortricidae) (62%), primarily due to *Scambus* spp. and *Orgilus scaber* Muesebeck (Hymenoptera: Braconidae) in the former and *Triclistus* spp. (Hymenoptera: Ichneumonidae) in the latter.

Pine Shoot Beetle, *Tomicus piniperda* (L.) (Coleoptera: Curculionidae), a European species, was first found in the Niagara region in 1993 (Bright 1996). Parasitoids found in his study included *Coeloides pissodis* (Ashmead), *Spathius* sp. (Hymenoptera: Braconidae), *Dinotiscus dendroctoni* (Ashmead), *Rhopalicus tutela* (Walker), *Roptrocerus xylophagorum* (Ratzeburg) (Hymenoptera: Pteromalidae), *Eupelmus* sp. (Hymenoptera: Eupelmidae) and *Eurytoma* sp. (Hymenoptera: Eurytomidae). Predators included *Platysoma gracile* LeConte (Coleoptera: Histeridae), *Corticeus praetermissus* (Fall) (Coleoptera: Tenebrionidae), *Medetera signaticornis* (Loew) and *M. pinicola* Kowarz (Diptera: Dolichopodidae). Most of the species found are habitat-specific rather than host-specific, thus any bark beetle encountered under the bark may be a suitable host. A few parasitoid species, e.g., *Eupelmus* sp., may be hyperparasitoids. It was concluded that further investigation of the role of native natural enemies would provide evidence on whether or not there is a need to introduce exotic natural enemies.

Potato Leafhopper, *Empoasca fabae* Harris (Hemiptera: Cicadellidae), is a pest of a variety of field crops such as edible beans, potatoes, alfalfa, peanut and soybean (Appleton et al. 2004). They concluded that predators and parasitoids were not effective

regulators of potato leafhopper populations, despite egg parasitism up to 40% by *Anagrus armatus* (Ashmead) (Hymenoptera: Mymaridae). Although the fungus *Zoophthora radicans* (Brefeld) Batko (Entomophthoraceae) caused epizootics, the narrow environmental conditions required for this are rare in Ontario; thus it was not considered to be a reliable control.

Redbanded Leafroller, *Argyrotaenia velutinana* (Walker) (Lepidoptera: Tortricidae) is a native species that occurs on broad-leaved trees in eastern North America (Hikichi 1971). In response to increasing outbreaks in apple orchards in Ontario, Hikichi (1962) studied its mortality factors. *Trichogramma minutum* parasitized ~2% of the eggs collected, ~50% of larvae were infected by a granulovirus and another ~12% of larvae were parasitized by *Phytodietus vulgaris* Cresson (Hymenoptera: Ichneumonidae). The study concluded that disease and drought conditions that reduced foliage quality were the primary factors contributing to mortality of *A. velutinana*.

Six-spotted Leafhopper, *Macrosteles fascifrons* (Stål) (Hemiptera: Cicadellidae), is an important vector of aster-yellows virus (Miller and De Lyzer 1960). They conducted field surveys but only a single parasitoid species, *Epigonatopus plesius* Fenton (Hymenoptera: Dryinidae) was recovered from adults and levels of parasitism were not considered of economic importance.

Soybean Aphid, *Aphis glycines* Matsumura (Hemiptera: Aphididae), native to eastern Asia, was first reported in Ontario in 2001 (Ragsdale et al. 2004). Bahlai and Sears (2009) studied the population dynamics of soybean aphid and the predator *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in vineyards in the Niagara region. They found that high populations of *H. axyridis* were correlated with substantial numbers of soybean aphid when aphids occurred early in the season. However, outbreaks of *H. axyridis* in vineyards were observed when the numbers of soybean aphid eggs were fewest on overwintering buckthorn, *Rhamnus* spp. (*Rhamnaceae*), plant hosts. The availability of high numbers of eggs, oviposited by soybean aphid late in the season on the winter host plant, served to divert *H. axyridis* from feeding on ripening grapes in vineyards. Thus Bahlai and Sears (2009) showed that high numbers of aphids in soybean did not result in high numbers of *H. axyridis* invading vineyards. They proposed a 'kick start/distract' model to explain these dynamics and provide a basis for integrated management.

Spotted Tentiform Leafminer, *Phyllonorycter blancardella* (Fabricius) (Lepidoptera: Gracillariidae) an invasive alien pest from the Palaearctic is an important pest of apples in central Ontario as well as other parts of eastern Canada (Vincent et al. 2013). Johnson et al. (1977) studied the seasonal occurrence and natural enemies of this pest in Ontario apple orchards. They reported that the endoparasitic *Pholetesor ornigis* (Weed) (Hymenoptera: Braconidae) was the dominant parasitoid (up to 57% parasitism) and was well-synchronized with the 1st and 3rd host generations. *Sympiesis gordius* (Walker), *S. sericeicornis* (Nees), *Pnigalio minio* (Walker), *P. uroplatae* (Howard), *Chrysocharis nepereus* (Walker) and *Closterocerus* sp. (Hymenoptera: Eulophidae) impacted 1st and 2nd generation spotted tentiform leafminer, the first three species being most prevalent, although overall parasitism was at most 24%. Predation was not significant.

Tarnished Plant Bug, *Lygus lineolaris* (Palisot) (Hemiptera: Miridae) is a widespread and important pest of vegetable, fruit, greenhouse, and field crops, particularly those grown for seed (Broadbent et al. 2013). Broadbent et al. (1999) reared five parasitoid

species, including *Leiophron mellipes* (Cresson), *L. digoneutis* (Loan), *L. pseudopallipes* (Loan), *Leiophron lygivora* (Loan), and *L. rubricollis* (Thomson) (Hymenoptera: Braconidae). Mason et al. (2011) examined the effect of periodic cutting of alfalfa on parasitism of tarnished plant bug and alfalfa plant bug, *Adelphocoris lineolatus* (Goeze) (Hemiptera: Miridae) by *Leiophron* spp. Although populations of hosts and parasitoids declined in cut habitats, they did not go extinct and recolonization by adults sustained parasitoid populations.

Trefoil Seed Chacid, *Bruchophagus platyptera* (Walker) (Hymenoptera: Eurytomidae) is an important pest of alfalfa, clover and trefoil seed crops (Ellis and Nang'ayo 1992). These authors discovered two parasitoids, *Mesopolobus bruchophagi* (Gahan) and *Tetrastichus bruchophagi* Gahan (Hymenoptera: Pteromalidae) at levels of 8.2 and 11.0%, respectively. Parasitoids were not present in all fields and were more likely to occur in older fields. They noted that these same species occur elsewhere in North America where trefoil seed chacid is found.

White Pine Weevil, *Pissodis strobi* (Peck) (Coleoptera: Curculionidae), native to North America, is a major pest in pine plantations in most of Canada and the USA (Hulme and Kenis 2002). Wallace and Sullivan (1985) reviewed its biology, highlighting aspects that could be exploited to manage the pest. Among major larval and pupal mortality factors identified were the predator *Lonchaea corticis* Taylor (Diptera: Lonchaeidae) and the parasitoids *Eurytoma pissodes* Girault (Hymenoptera: Eurytomidae) and *Dolichotomitus terebrans nubilipennis* (Viereck) (Hymenoptera: Ichneumonidae).

Willow Gall Fly, *Rhabdopahaga strobiloides* Walsh (Diptera: Cecidomyiidae) was studied by Judd (1953). In addition to willow gall fly which induces the galls, the inquiline *Dasyneura albovittata* Walsh (Diptera: Cecidomyiidae) was reared from these galls, as was a single female sawfly, *Amauronematus* sp. (Hymenoptera: Tenthredinidae). Parasitoids reared from willow gall fly included *Copidosoma* sp., (Hymenoptera: Encyrtidae), *Tridymus* sp. (Hymenoptera: Pteromalidae), and *Torymus cecidomyae* (Walker) (Hymenoptera: Torymidae). *Leptacis* sp. (Hymenoptera: Platygasteridae), *Ceraphron* sp. (Hymenoptera: Ceraphronidae), *Tetrastichus* sp. (Hymenoptera: Eulophidae) and *Torymus* sp. were reared from cocoons of *D.albovittata*. Among the remaining parasitoids reared were *Adialytus salicaphis* (Fitch) and *Aphidius matricariae* Haliday (Hymenoptera: Braconidae), known parasitoids of aphids, and *Microgaster hospes* Marshall (Hymenoptera: Braconidae) and *Pediobius* sp. (Hymenoptera: Eulophidae), parasitoids of Lepidoptera. The hyperparasitoids *Lygocerus* sp. (Hymenoptera: Cephronidae) and *Alloxysta* sp. (Hymenoptera: Alloxystidae) were reared, probably from *A. phorodontis*.

2. General Studies of Natural Enemy Communities

Natural enemy surveys that are not pest specific provide a broad perspective of the complexes present in different habitats. Several studies published in JESO documented natural enemies associated with particular pests or crop systems, often to evaluate the impacts of management systems or pesticides on these communities. Other studies appear to have been opportunistic and documented natural enemies associated with host species likely encountered fortuitously during field trips focusing on other topics.

Field crop habitats. Ben-Ze'ev and Jaques (1990) surveyed alfalfa fields in southwestern Ontario for entomopathogens. The invasive Alfalfa Weevil, *Hypera postica*

(Gyllenhal) (Coleoptera: Curculionidae) was infected by *Erynia phytonomi* (Arthur) Humber, Ben-Ze'ev and Kenneth, *Erynia* sp. (Entomophthoraceae) and *Beauveria bassiana* (Balsamo) Vuillemin (Moniliaceae). *Conidiobolus obscurus* (Hall and Dunn) Remaudière and Keller, *C. thromboides* Dreschler (Ancylistaceae), *Entomophthora planchoniana* Cornu, *Erynia neoaphidis* Remaudière and Hennebert (Entomophthoraceae), and *Neozygites fresenii* (Thaxter) Remaudière and Keller (Neozygiotaceae) were associated with a mixed population of Pea Aphid, *Acyrthosiphon pisum* (Harris), Black Bean Aphid, *Aphis fabae* Scopoli, and the Green Peach Aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae). *Entomophthora muscae* (Cohn) Fresen (Entomophthoraceae) complex was associated with the Seedcorn Maggot, *Delia platura* (Meigen) (Diptera: Anthomyiidae). *Erynia echinospora* (Thaxter) Remaudière and Keller [or *E. dipterigena* (Thaxter) Remaudière and Keller] was associated with Lauxaniidae (Diptera). *Erynia petchii* (Ben-Ze'ev and Kenneth) was associated with the Meadow Spittlebug, *Philaenus spumarius* (L.) (Hemiptera: Cercopidae) and *Zoophthora radicans* (Brefeld) Batko was associated with the Potato Leafhopper, *Empoasca fabae* Harris (Hemiptera: Cicadellidae) and Aphididae. The study concluded that entomopathogens have a role in natural regulation of pest insects and there is potential for their introduction (e.g., *B. bassiana* and *Erynia* spp.) to supplement other biological control agents to manage *H. postica* populations.

Orchard habitats. Hagley (1979) studied the effects of insecticides on natural predator populations in apple, *Malus* spp. (*Rosaceae*), orchards. *Hippodamia tridecempunctata tibialis* (Say) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) were the most abundant predators collected. *Phytocoris* sp., *Deraeocoris fasciolus* Knight and *Plagiognathus obscurus* (Uhler) (Hemiptera: Miridae) were the main true bug species encountered, and *Chrysopa oculata* (Say) (Neuroptera: Chrysopidae), *Hemerobius humulinus* (L.) (Neuroptera: Hemerobiidae), *Epiodes americanus* Wiedemann, *Allograpta obliqua* (Say) (Diptera: Syrphidae), *Cantharis* sp. and *Podabrus* spp. (Coleoptera: Cantharidae) commonly occurred. Overall, predator populations were low and insecticide treatments (phosmet and azinphosmethyl) appeared to reduce eggs and immature stages of the predators. Most adult predators collected immigrated from outside of treated areas. Thus, numbers of predators in natural areas was insufficient to provide effective control of the major pests: codling moth, apple maggot, and Plum Curculio, *Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae). Hagley (1979) concluded that augmentation of predator numbers is required when management practices use insecticides.

Woolhouse and Harmsen (1985) studied the population dynamics of the mite complex on foliage of a pesticide-free apple orchard. Over a 3-year period, population dynamics were highly variable but pest species did not reach economic thresholds. *Zetzellia mali* (Ewing) (Trombidiformes: Stigmaeiidae) and Phytoseiidae species tracked changes in prey abundance. *Zetzellia mali* was more closely linked to eriophyid rust mites, *Aculus* sp., abundance while the Phytoseiidae were linked to tetranychid, i.e., Two-spotted Spider Mite and European Red Mite, abundance. *Zetzellia mali* and Phytoseiidae were more abundant on trees nearer the orchard edge suggesting the acaricide spray programs that focus on the central parts of an orchard could be less detrimental to predator populations. They concluded that pest populations tend to be lower, sometimes by an order of magnitude, on McIntosh and Golden Delicious varieties than on Red Delicious and Empire varieties in a predator-rich environment.

Non-crop habitats. Laing and Welch (1963) reported feeding by adults of the predaceous fly, *Dolichopus gratus* Loew (Diptera: Dolichopodidae), on larvae of *Culex restuans* Theobald (Diptera: Culicidae). Edwards and Pengelly (1966) reported parasitism of *Bombus fervidus* (Fabricius) (Hymenoptera: Apidae) by *Melittobia chalybii* Ashmead (Hymenoptera: Eulophidae). Loan (1973) reported the first occurrence of parasitism of adult *Notoxus anchora* Hentz (Coleoptera: Anthicidae) by *Centistes agilis* (Cresson) (Hymenoptera: Braconidae); the level of parasitism was 7%.

3. Natural Enemy Biology

Understanding the biology of natural enemies provides guidance for the development and conservation of agents to better manage key pests. Since 1952, five JESO studies described methods to improve rearing of natural enemies useful as biological control agents while another 18 studied performance of potential biological control agents. Four other studies described the basic biology of particular natural enemies to better understand development, behaviours or species interactions. Finally, four studies looked at how particular pesticides affected the biology of natural enemies.

Rearing of natural enemies. Maybee (1956) described a method for rearing the exotic parasitoid *Basalys tritomus* Thomson (Hymenoptera: Diapriidae) on *Drosophila melanogaster* Meigen (Diptera: Drosophilidae) in the laboratory. West and DeLong (1956) studied the biology of and developed a rearing method for *Zelus exsanguis* (Ståhl) (Hemiptera: Reduviidae), a generalist predator found in Ontario commonly found feeding on larvae of the forest tent caterpillar. They successfully reared three generations in the laboratory; cannibalism appeared to be an important consideration because it affects survival of newly hatched nymphs.

Corrigan et al. (1990) studied the pupal orientation and emergence success of *Horismenus puttleri* (Grissell) (Hymenoptera: Eulophidae), imported from Central America for biological control of Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae). Because *H. puttleri* is unable to overwinter in temperate North America, mass production for inundative releases was considered as the best option to use this agent. Location of host eggs on leaf surfaces influenced parasitoid pupal orientation and emergence. When egg masses faced down (i.e., underside of leaf) 98% of parasitoids pupated with their head down and 89% of adult *H. puttleri* emerged successfully. In contrast, when egg masses faced up (i.e., upper side of leaf) 63% of *H. puttleri* individuals faced down (head faced the leaf surface) and 66% of adult parasitoids emerged successfully.

Corrigan and Laing (1992) studied an improved method for producing small, consistent samples of hosts for presentation to the egg parasitoid, *Trichogramma minutum*. They described a new sampling strip to decrease preparation times and reduce damage to host *Ephestia kuehniella* Zeller eggs (Lepidoptera: Pyralidae). Corrigan et al. (1994) studied the feasibility of delaying emergence of *T. minutum* and subsequent effects on adult longevity and fecundity. Adult longevity of individuals reared at 16°C increased in direct proportion to the length of time they were held as pre-adults at this temperature, compared to 25°C. However, offspring production was reduced when reared at 16°C, although reproductive potential was not affected by length of time at 16°C or 12L:12D conditions. The results indicated that under the conditions studied emergence from *E. kuehniella* eggs

was not sufficiently delayed and rearing at lower temperatures (i.e., 16°C) adversely affected reproductive performance.

Performance of biological control agents. James (1959) studied egg development, hatching and prey consumption in several habitats by *Mantis religiosa* L. (Orthoptera: Mantidae), introduced from Europe in the early 1900s. Egg development differed among habitats but did not affect hatching. He found that prey abundance, primarily field crickets, influenced number of and size of egg masses indicating the importance of this prey for maintaining local populations of *M. religiosa*.

Loan (1964) studied the biology of *Centistes ater* (Nees) (Hymenoptera: Braconidae), an internal parasitoid of adult *Sitona* spp. (Coleoptera: Curculionidae), as a biological control agent of *S. lineellus* (Bonsdorff) in Canada. In the field, *C. excrucians* is well synchronized with the univoltine *S. lineellus*. The parasitoids overwintered as mature larvae in adult weevils, emerging the following spring in late April or May, depending on temperature, to pupate in the soil. Adult *C. ater* emerged in late June–early July when the summer-emerged adult *S. lineellus* were present.

Loan (1965) described the life cycle and development of *Leiophron mellipes* (Cresson) in five Miridae (Hemiptera) hosts in southern Ontario. Adults were present from May to September. Immature stages were found in *Labops hirtus* Knight (late May to mid-June, 20% parasitism), *Leptopterna dolobrata* (L.) (mid-May to end of June, 42% parasitism), *Adelphocoris lineolatus* (Goeze) and *A. rapidus* Say (June, 49% and 60%, respectively), and *Lygus lineolaris* (Hemiptera: Miridae) (June-July, 46% parasitism, and August-September, 12% parasitism). A single generation of *L. mellipes* occurred in each host species, although each of the two distinct generations of *L. lineolaris* were parasitized.

Griffiths (1972) studied the discrimination ability of the parasitoid *Pleolophus basizonus* (Gravenhorst) (Hymenoptera: Ichneumonidae) introduced from 1939–1949 for biological control of the invasive European Pine Sawfly, *Neodiprion sertifer* (Geoffroy) (Hymenoptera: Diprionidae). Although unable to detect hosts containing eggs of conspecifics, *P. basizonus* were able to detect hosts containing later developmental stages. *Pleolophus basizonus* was also recovered from two other introduced and seven native sawflies.

Reid and Harmsen (1975) studied the biology of *Trihabda borealis* Blake (Coleoptera: Chrysomelidae) on goldenrod, *Solidago canadensis* (Kirby) (*Asteraceae*). They determined *T. borealis* is of major importance as a phytophage on *S. canadensis* in southeastern Ontario, although serious defoliation was rare.

Ramey (1990) studied the host identification and oviposition behaviour of *Eurytoma obtusiventris* Gahan (Hymenoptera: Eurytomidae), a parasitoid of *Eurosta solidaginis* (Fitch) (Diptera: Tephritidae) that live in galls of goldenrod (*Solidago* spp.). Female *E. obtusiventris* preferred stems of *Solidago altissima* L. infested with *E. solidaginis* but also explored *S. altissima* stems without fly larvae, although females only oviposited in plants containing host larvae. He also showed that *E. obtusiventris* females prefer *S. altissima* infested plants over infested *S. canadensis* plants.

George (1979) studied the potential of *Dugesia tigrina* (Girard) (Tricladida: Duegesiidae) for control of mosquitoes in Ontario. Field tests showed that *D. tigrina* reduced populations of *Culex restuans* and *C. pipiens* L. (Diptera: Culicidae) by 17 times (4/dip versus 69/dip in control treatments). Low oxygen levels and toxins such as turpentine and paint were important mortality factors of *D. tigrina* in catch basins (George 1984).

Loan (1982) developed a field technique to study the interaction of the fungi *Zoophthora* spp. (Entomophthoraceae) and the parasitoid *Perilitus colesi* (Drea) (Hymenoptera: Braconidae) both of which attack larvae of the alfalfa weevil. Foliar applications of the fungicide captafol protected weevil larvae from attack by *Zoophthora* spp. The study confirmed earlier findings that peak attack by *M. colesi* occurred after disease epizootics caused by *Zoophthora* spp. began to subside.

Bolter and Laing (1984) studied competitive interactions between *Diadegma insulare* and *Microplitis plutellae* for larvae of diamondback moth. Development of both parasitoids was synchronized with that of the host. At 23°C average fecundity was 814 eggs per female for *D. insulare* and 316 eggs per female for *M. plutellae*. Degree-day development from egg to adult was 282 above 6.6°C for *D. insulare* and 218 above 9.2°C for *M. plutellae*. *Diadegma insulare* avoided superparasitism and multiple parasitism of larvae already parasitized by *M. plutellae*. In contrast, *M. plutellae* avoided superparasitism but could not detect eggs of *D. insulare* for at least 12 h after they were oviposited in the host. When eggs of both species were oviposited at the same time, 1st instar *M. plutellae* was intrinsically superior to 1st instar *D. insulare*. However, 2nd and 3rd instar *D. insulare* were superior to 1st instar *M. plutellae*.

Clements (1989) studied the role of the stigmaeid mite, *Z. mali* in orchards. *Zetzellia mali* fed on the European red mite and the Apple Rust Mite, *Aculus schlechtendali* (Nalepa) (Trombidiformes: Eriophyidae) but did not interfere with the phytoseiid mite *Typhlodromus caudiglans* (Schuster) (Mesostigmata: Phytoseiidae), either by intraguild predation or competition.

Whistlecraft and Lepard (1989) studied the effect of flooding on the survival of the Onion Maggot, *Delia antiqua* (Meigen) (Diptera: Anthomyiidae), and two of its parasitoids, *Aphaereta pallipes* (Say) (Hymenoptera: Braconidae) and *Aleochara bilineata* Gyllenhal (Coleoptera: Staphylinidae). Survival of *A. pallipes* was greater than or equal to that of its host while survival of *A. bilineata* was less, even at temperatures below the developmental threshold (1°C). This suggested that flooding of fields to control *D. antiqua* may lead to elimination of *A. bilineata* populations. Whitfield et al. (1981) developed a computer model to simulate the interaction between onion maggot and *A. pallipes*, a larval parasitoid. The model determined that *A. pallipes* reduced 2nd and 3rd generation maggot populations, resulting in a 70% profit gain. As well, the model provided guidance on when spray applications would least affect parasitoids.

Wang and Laing (1989) studied the reproductive biology of the introduced *Ageniaspis testaceipes* (Ratzeburg) (Hymenoptera: Encyrtidae), an egg-larval parasitoid, and its effect on the spotted tentiform leafminer. Potential fecundity of *H. testaceipes* was 25 eggs per female and an average of 9.1±3.4 broods were produced over an average lifespan of 7.5±2.7 days. Although newly oviposited host eggs were preferred, eggs up to 5 days old were successfully parasitized and parasitoid development took 35–37 days at 25°C. Development of parasitized *H. testaceipes* was delayed and these individuals were larger than unparasitized individuals. The longer feeding period and larger size of parasitized spotted tentiform leafminer larvae suggest that *H. testaceipes* may consume more foliage, however, this may also increase the size and/or number of parasitoids. They concluded that the attribute that female *H. testaceipes* may oviposit into host eggs of any age provides a

larger window of opportunity for oviposition, facilitating synchronization with its host and improve efforts to establish *H. testaceipes* in North America.

Song (1990) studied the potential for *Gelis tenellus*, a hyperparasitoid, to influence parasitism of gypsy moth by *Cotesia melanoscela* (Ratzeburg) (Hymenoptera: Braconidae). *Gelis tenellus* produced significantly more eggs when hosts were available on a daily basis versus every third day. Nealis and Bourchier (1995) compared the vulnerability to hyperparasitism of different European and Asian strains of *Cotesia melanoscela*, a biological control agent of gypsy moth. Rates of predation and hyperparasitism were not related to cocoon morphology but were dependent on length of time cocoons were exposed to hyperparasitism in the field. The nondiapause characteristics of the Asian strain decreased its exposure time and therefore reduced vulnerability to hyperparasitism. Thus, inundative releases of nondiapause strains early in the season were likely to minimize exposure of *C. melanoscela* to hyperparasitism, which currently is 95% over the summer. They also concluded that diapause of already established local strains of *C. melanoscela* could be manipulated by varying photoperiod during larval development, thus release of additional exotic strains would not be required.

Villaneuva and Harmsen (1996) studied the ecological interactions of tarsonemid mites in apple orchards. *Dendroptus* n. sp. near *suskii* Sharonov and Livshitz (Trombidiformes: Tarsonemidae) was identified as a predator of apple rust mite and contributed to the mid-summer decrease of this pest.

Jones et al. (2006) studied the influence of greenhouse microclimate on predation of Western Flower Thrips, *Franklinella occidentalis* (Pergande) (Thysanoptera: Thripidae) by *Neoseiulus cucumeris* (Oudemans) (Mesostigmata: Phytoseiidae). Leaf temperature was positively correlated with predation and oviposition by *N. cucumeris*, suggesting that seasonal adjustments in release of this biological control agent could be made.

Development, behaviour and species interactions. Vander Hoek (1971) described the larval instars of *Aphidius nigripes* Ashmead (Hymenoptera: Braconidae), a common parasitoid of the pea aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae). Five instars were documented based on changes in cuticular structure observed at 24 h intervals.

Bennett (2004) studied the host location behaviour of *Pelecinus polyturator* (Drury) (Hymenoptera: Pelecinidae) a common endoparasitoid of june beetles, *Phyllophaga* spp. (Coleoptera: Scarabeidae). Host location consisted of wandering on the surface until the antennae ceased moving and the distal abdominal segments appeared to touch the surface. Then a series of movements would push the distal segment into the soil, penetrating up to 5 cm. The procedure lasted about 145 seconds.

Macfarlane and Pengelly (1978) studied *Brachioma* spp. (Diptera: Sarchophagidae), and the eulophid *Melittobia chalybii* Ashmead (Hymenoptera: Eulophidae), parasites of the brood of *Bombus* spp. in southern Ontario. They reported *Brachioma setosa* Coquillett as a parasite of *Bombus* for the first time and found that 2–3 generations occurred each season. As well, *M. chalybii* attacked both *Bombus* spp. and *B. setosa*. They found that these parasites attacked larvae of *Bombus* spp. and infested colonies had fewer workers and died out more quickly than unparasitized colonies.

Wright and Laing (1979) reported on the effects of temperature on development, adult longevity and fecundity of *Coleomegilla maculata lengi* Timberlake (Coleoptera:

Coccinellidae) and its parasitoid *Dinocampus coccinellae* (Shrank) (Hymenoptera: Braconidae). A total of 198.8 degree-days (above 13.8°C) were required for development of *C. maculata lengi* from egg to adult while 180.5 degree-days (above 11.2°C) were required for *D. coccinellae* development. *Coleomegilla maculata lengi* produced an average of 191.5 eggs per female and longevity averaged 82.3 days. *Dinocampus coccinellae* survived for 5 days when continuously exposed to hosts and produced an average of 66.8 eggs per female at 25°C. Earlier studies had estimated potential fecundity of *D. coccinellae* at 200–400 eggs per female, thus it appeared that realized fecundity was limited by the ability of females to find hosts. Wright (1979) observed the copulatory behaviour of *C. maculata lengi*. The male mounted females from behind and assumed the dorsal position as is normal for braconids. Copulation lasted for 18–20 min, considerable longer than the <1 min known for other braconids.

Effects of pesticides on natural enemies. Robinson (1953) described the biology of *Stethorus punctum* (LeConte) (Coleoptera: Carabidae) and determined that DDT and methoxychlor were lethal to adults, killing 47.1 and 60%, respectively, in laboratory experiments. Fisher (1988) reported on the effects of pesticides on *Pholetesor ornigis* (Weed) and *P. pedias* (Nixon) (Hymenoptera: Braconidae), parasitoids of the spotted tentiform leafminer. The number of days to 50% mortality (LT50) of *Pholetesor pedias* was higher than for *P. ornigis* when exposed to azinphosmethyl and permethrin.

Hagley and Laing (1989) studied the effect of pesticides on parasitism by *T. minutum* and *T. pretiosum* Riley (Hymenoptera: Trichogrammatidae) of eggs of codling moth. The insecticides azinphosmethyl, difluibenzuron, permethrin, and methomyl were toxic, as was the acaricide cyhexatin. Triflumuron, a lower rate of diflubenzuron (1/3 of recommended dose), and the fungicides captan, dodine and polyram did not affect parasitism.

Wang and Laing (1990) studied the toxicity of methomyl, permethrin, azinphosmethyl and phosmet to adult *Ageniaspis testaceipes*, an introduced egg-larval parasitoid of the spotted tentiform leafminer. At the time, these insecticides were used to control spotted tentiform leafminer, the plum curculio, codling moth and apple maggot in Ontario orchards. They concluded that understanding tolerance levels of *A. testaceipes* to pesticides used is essential for integrating this biological control agent into management programmes. For example, methomyl and permethrin residues caused higher mortality of *A. testaceipes* than azinphosmethyl and phosmet, although responses of individual females were highly variable to the latter two products.

4. Classical Biological Control of Weeds

Studies on classical biological control of weeds reported in JESO have been few and none are comprehensive. A great deal of the work in this area relevant to Ontario has been published elsewhere (e.g., The Canadian Entomologist). In JESO there are publications on various aspects of exotic phytophagous-feeding insects introduced for biological control of five non-native weed species (Table 1). Three species are on the Noxious Weeds in Ontario list (Anonymous 2013) and all are treated in the *Ontario Weeds* guide (Alex, 1998). The publications summarized here report on the status, at the time of publication, of introduced species.

Canada Thistle, *Cirsium arvense* (L.) Scopoli (*Asteraceae*), is a noxious and widespread weed in Ontario, most abundant in southern areas (Moore, 1975). *Urophora*

cardui L. (Diptera: Tephritidae) was introduced for its biological control (Laing 1978). Three years after initial releases in 1975, 40% of host plants around the release site contained galls of *U. cardui* and the agent had spread to plants several hundred meters from the release site.

Leafy Spurge, *Euphorbia esula* L. (*Euphorbiaceae*), is a noxious and widespread weed in Ontario (Best et al. 1980). LeSage (1996a) reported that populations of the introduced biological control agent, *Aphthona nigriscutis* Foudras (Coleoptera: Chrysomelidae) increased significantly in 1994 and 1995 but did not damage leafy spurge. The survey also yielded specimens of *A. flava* Guillebeau, a related exotic species that had not been approved for release, suggesting that some individuals in the released population were misidentified.

Nodding Thistle, *Carduus nutans* L. (*Asteraceae*), is a noxious and widespread weed in Ontario where it is most abundant, although it occurs throughout Canada (Desrochers et al. 1988). Laing and Heels (1979) reported that three years after 1975 releases, *Rhinocyllus conicus* Frölich (Coleoptera: Curculionidae) was well established around Guelph. Infestation levels up to 95% (24–95%) were recorded. Thistle seed heads with 7+ pupal cells of *R. conicus* produced significantly reduced amounts of seed than those seed heads with 0–6 pupal cells.

Purple Loosestrife, *Lythrum salicaria* L. (*Lythraceae*), is highly abundant in the Great Lakes Basin and along the St. Lawrence River (Mal et al. 1992). Corrigan et al. (1998) conducted a study on potential non-target feeding by *Neogalerucella calmariensis* (L.) (Coleoptera: Chrysomelidae) introduced for biological control of this invasive plant. The study was initiated based on the field observations of *G. calmariensis* feeding on cuttings of Swamp Loosestrife, *Decodon verticillatus* (L.) Elliott, and egg masses on Winged Loosestrife, *Lythrum alatum* Pursh (*Lythraceae*), at the Ontario Royal Botanical Garden where large populations of *N. calmariensis* were present. Monitoring of all three plant species through two generations of the beetle revealed that *L. salicaria* plants sustained moderate to complete defoliation in all areas monitored. Several *D. verticillatus* and *L. alatum* plants were slightly damaged by *N. calmariensis* feeding and about 15 egg masses were found when several hundred of these non-target plants were examined. No late instar larvae were found on either *D. verticillatus* or *L. alatum*. The results suggested that the minimal feeding and few egg masses represent a 'spill-over' effect that occurred when large numbers of *N. calmariensis* were dispersing from locations where *L. salicaria* populations had been significantly reduced.

St. John's Wort, *Hypericum perforatum* L. (*Hyperiaceae*) is found in the Great Lakes-St. Lawrence regions of Ontario (Crompton et al. 1988). LeSage (1996b) reported on the presence in the Gatineau area of Quebec of *Chrysolina hyperici* (Förster) (Coleoptera: Chrysomelidae), introduced for biological control of St. John's wort. The agent had dispersed 145 km from the release site in Belleville, Ontario, at an estimated rate of 6 km per year.

5. Classical Biological Control of Arthropods

Introduction of exotic species for the biological control of arthropods has been reported in JESO for 15 invasive species (Table 2). All but one of these papers (Maxwell and Morgan 1952) treated pests of agriculture crops or trees in Ontario. The JESO studies summarized here for each target species report on the status of introduced biological

control agents, i.e., whether established or not, and document native natural enemy species associated with the targets at the time of publication.

Alfalfa Blotch Leafminer, *Agromyza frontella* (Rondani) (Diptera: Agromyzidae), invaded Ontario in the mid 1970s. Coote and Ellis (1987) studied the parasitoids of alfalfa blotch leafminer near Guelph in 1983–1984. Four parasitoids, *Diglyphus begini* (Ashmead), *D. intermedius* (Girault), *D. pulchripes* (Crawford) and *Pnigalio maculipes* (Crawford) (Hymenoptera: Eulophidae) were reared from larvae. *Cyrtogaster vulgaris* Walker (Hymenoptera: Pteromalidae) and *Chrysocharis giraulti* Yoshimoto (Hymenoptera: Eulophidae) were reared from pupae. Overall parasitism was low, averaging 3.4% due in part to poor synchrony of the parasitoids with the host. One additional species, *Diglyphus isaea* (Walker) (Hymenoptera: Eulophidae) was collected from alfalfa plants. Parasitoids emerged later in the spring than alfalfa blotch leafminer, thus parasitizing only 2nd and 3rd generation hosts. *Diglyphus intermedius* was the most abundant of the larval parasitoids and the three *Diglyphus* spp. accounted for 75% of the parasitoids reared from hosts. *Diglyphus isaea* and *C. vulgaris* are exotic parasitoids and were reported for the first time in Ontario and in association with alfalfa blotch leafminer. All but one of the pupal parasitoids was *C. vulgaris* and parasitism levels were low, averaging <1% but were highest at 3.3% in the 3rd generation, although sampling included only the few pupae on plants and not those in soil where alfalfa blotch leafminer normally pupates. It was concluded that the existing parasitoid complex was unlikely to maintain alfalfa blotch leafminer below economic thresholds and exotic species already established in the USA would be suitable for introduction. Harcourt et al. (1987) reported that the European larval-pupal endoparasitoid *Dacnusa dryas* (Nixon) (Hymenoptera: Braconidae), first released in1979 near Ottawa, became well established in most counties of southern Ontario, with rates of attack averaging 84% (65–95%). Dispersal from nursery plots and natural spread from release sites and life table data indicated that alfalfa blotch leafminer populations declined less than three years after release of *D. dryas*.

Alfalfa Weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae), of European origin, was first reported in the Great Lakes region in the early 1960s. Abu and Ellis (1976) studied *Bathyplectes curculionis* (Thomson) (Hymenoptera: Ichneumonidae) a larval parasitoid of alfalfa weevil and found that although spring emergence of *B. curculionis* was synchronized with that of alfalfa weevil larvae, parasitism levels were low early in the season (6.3–33.3%) when host populations were highest, increasing later in the season (60–68%) when host populations were declining. High rates of diapause in 1st generation parasitoid larvae were thought to be responsible for the lower initial parasitism. Several hyperparasitoids, *Gelis* sp., *Trichomalopsis viridescens*, *Pteromalus* sp. and *Eupelmella vesicularis* (Retzius) (Hymenoptera: Eupelmidae) were reared from 24% of *B. cuculionis*. Harcourt et al. (1980) studied the distribution of the European exotic *Perilitus aethiops* Nees (Hymenoptera: Braconidae), a parasitoid that attacks adults of alfalfa weevil. First released in Ontario in 1970–1971, *P. aethiops* became widely established in southern Ontario by 1979, where parasitism levels of the spring generation of alfalfa weevil averaged 60% (13–92%). Harcourt et al. (1982) conducted a survey for *Perilitus colesei* (Drea), a larval parasitoid introduced in 1970 and found that *P. colesi* was present in 39 of 41 counties, with parasitism levels averaging 13% (1–52%). Although two fungal pathogens also attack alfalfa weevil larvae, *M. colesi* emerges from cocoons in late May or early June and attacks larger

host larvae, likely after epizootics have subsided and therefore it is able to coexist with the disease agents. The widespread distribution of *M. colesi* is probably the result of dispersal from the USA into southwestern Ontario and dispersal from the release site in Prince Edward County in eastern Ontario. Harcourt and Ellis (1992) determined that the larval parasitoid *Bathyplectes anurus* (Thomson) (Hymenoptera: Ichneumonidae), introduced in 1970, had become widespread in southern Ontario and had displaced *B. curculionis* as the main larval parasitoid of *H. postica*. Abundance of this parasitoid was influenced by the fungal pathogen *Zoophthora phytonomi* (Arthur) Batko (Entomophthoraceae), which dominated during wet periods while *B. anurus* increased during successive dry springs.

Carrot Rust Fly, *Psila rosae* (Fabricius) (Diptera: Psilidae) was introduced around 1885. Releases of *Chorebus posticus* (Haliday) (Hymenoptera: Braconidae), a larval parasitoid, and *Basalys tritoma*, a pupal parasitoid, were made from 1949–1953 in Ontario, British Columbia, and Prince Edward Island (Maybee 1954). Although recoveries were made in the year of release neither *C. posticus* nor *B. tritoma* were collected the following winter.

Cereal Leaf Beetle, *Oulema melanopus* (L.), (Coleoptera: Chrysomelidae), was first found in southwestern Ontario in 1965 and became established in 1967 (McClanahan et al. 1968; Bierne 1971). McClanahan *et al.* (1968) reported that while no natural enemies were present in southwestern Ontario during the study, predators, parasitoids and diseases had been reported elsewhere in parts of North America invaded by this European pest. Ellis et al. (1979) reported that *Tetrastichus julis* (Walker) (Hymenoptera: Eulophidae), introduced into southern Ontario in 1974 as a biological control agent for cereal leaf beetle, had by 1977 expanded its range into the area north of Lake Huron and parasitism levels from 19–90% were documented. In areas where *T. julis* had been established since 1976, parasitism averaged 65%, indicating that it can maintain populations even when host densities are low. This successful biological control continued until an outbreak occurred in the central tobacco growing area of Ontario (Ellis et al. 1989). In a 1987 survey they reared a single *Anaphes* sp. from eggs of cereal leaf beetle and parasitism by *T. julis* was nil, despite high levels (~75%) of parasitism in other parts of the province. It was concluded that tillage, which kills 95% of overwintering *T. julis*, probably accounted for the absence of this agent in areas where crop rotations were practiced.

Codling Moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae), of southeastern European origin, was present in Ontario by 1858–1860 and a major apple pest by 1868 (Putnam 1963). In a review of the status of *C. pomonella* Putnam (1963) included what was known at the time about natural enemies. *Trichogramma minutum* was the only egg parasitoid associated with *C. pomonella*, while larval parasitoids included *Scambus pterophori* Ashmead (Hymenoptera: Ichneumonidae), *Dibrachys microgastri* (Bouché) (Hymenoptera: Pteromalidae), *Hymenochaonia delicata* (Cresson), *Macrocentrus ancylivora* Rohwer, *M. instabilis* Muesebeck, *Phanerotoma fasciata* Provancher (Hymenoptera: Braconidae), *Mastrus carpocapsae* (Cushman), *Temelucha minor* (Cushman), *Cryptus albitarsis* (Cresson), *Glypta* sp., *Aritranis* sp. (Hymenoptera: Ichneumonidae), and the adventive *Ascogaster quadridentata* Wesmael (Hymenoptera: Braconidae). *Dibrachys microgastri* was also found to be a hyperparasitoid of *A. quadridentata* as were *Perilampus fulvicornis* Ashmead, *P. tristis* Mayr and *Perilampus* sp. (Hymenoptera: Perilampidae), sometimes at levels of 72%. Pupal parasitism was negligible but included *D. microgastri*, *Eupelmus*

cyaniceps Ashmead (Hymenoptera: Eupelmidae), *Pimpla annulipes* Brullé, *Itoplectis conquisitor*, and *Eurytoma* sp. a hyperparasitoid. *Eupelmus cyaniceps* also parasitized the larval parasitoids *Macrocentrus* spp. and the pupal parasitoid *P. annulipes*. *Liotryphon caudatus* (Ratzeburg) and *Nippocryptus vittatorius* (Jurine) (Hymenoptera: Ichneumonidae) were introduced from France from 1941–1945 but failed to establish. *Elodia tragica* (Meigen) (Diptera: Tachinidae) and *Pristomerus vulnerator* (Panzer) (Hymenoptera: Ichneumonidae) were introduced from England in 1943–1944. *Ascogaster quadridentata, L. caudatus* and *N. vittatorius* were introduced into British Columbia but only *A. quadridentata* became established. The most important insect predators were the trogositid borer *Tenebroides corticalis* Melsheimer (Coleoptera: Trogossitidae), *Chrysopa carnea* (Stephens) and *C. rufilabris* Burmeister (Neuroptera: Chrysopidae), the egg feeding *Haplothrips faurei* Hood and *Leptothrips mali* (Fitch) (Thysanoptera: Phlaeothripidae), and the mite *Anystis agilis* Banks (Trombidiformes: Anystidae). Downy, *Dendrocopos pubescens* (L.), and hairy, *D. villosus* (L.) woodpeckers (Piciformes: Picidae) were important predators of codling moth. Several diseases have been isolated from codling moth, including *Bacillus cereus* from the Niagara Penninsula, *Beauveria bassiana* from Nova Scotia, and *Hirsutella subulata* Petch (Ophiocordycipitaceae) from the USA. *Mermis* sp. and *Neoaplectana* n. sp. (DD136) (Mermithidae) nematodes were also found infecting codling moth. Hagley (1970) studied codling moth to assess the importance of biotic and abiotic factors in regulating populations. He determined that disease (34.4–65.1%) and parasitism (31.9–80%) could be significant, although they were not uniform across orchards. Predation by birds was as high as 90%. Hagley (1987) surveyed the *Trichogramma* spp. in apple orchards in southern Ontario after inundative releases of *T. pretiosum* and *T. minutum*. Only *T. pretiosum* was recovered from sentinel codling moth eggs set out in 1982 and 1983. Parasitism ranged from 2.2–11.9% and parasitoids were recovered in both unsprayed and sprayed orchards. In 1984, *T. minutum* was the only species recovered in unsprayed orchards. The results indicated that *Trichogramma* spp. migrated into orchards from alternative hosts and occurred in low numbers early in the season. This and overall low natural parasitism suggested that augmentative releases and management of parasitoid populations could improve the success of biological control of coding moth.

Cranberry Fruitworm, *Acrobasis vaccinii* Riley (Lepidoptera: Pyralidae), in New Brunswick was the subject of a study showing that eggs were parasitized by *Phanerotoma franklini* Gahan (Hymenoptera: Braconidae) and that *Cryptus albitarsus albitarsus* (Cresson) (Hymenoptera: Ichneumonidae) emerged from overwintered larvae (Maxwell and Morgan 1952).

European Pine Shoot Moth, *Rhyacionia buoliana* (Denis and Schiffermüller) (Lepidoptera: Tortricidae), was introduced adventively from the USA into Ontario near Windsor in 1925 (Pointing and Green 1962). Coppel and Arthur (1954) provided an update on parasitoids introduced in Ontario to control it. From1928–1953 nine species, including *Campoplex difformis* (Gmelin), *Sinophorus turionum* (Ratzeburg), *Temeluca interruptor* (Gravenhorst), *Exeristes ruficollis* (Gravenhorst), *Pimpla turionellae* (L.), an unidentified *Pimpla* sp. (Hymenoptera: Ichneumonidae), *Orgilus obscurator* (Nees) (Hymeoptera: Braconidae), *Copidosoma filicorne* (Dalmen) (Hymenoptera: Encyrtidae), and *Baryscapus turionum* (Hartig) (Hymenoptera: Eulophidae) were released. Among the species recovered during post-release surveys, *C. interruptor* and *O. obscurator* accounted for more than 2/3

of all parasitoids. Overall parasitism was 1.96–10.86% and the native species, *Campoplex* sp., *Itoplectis conquisitor*, *Itoplectis* sp., *Scambus hispae* (Harris) (Hymenoptera: Ichneumonidae), *Eurytoma appendigaster* (Swederus) (Hymenoptera: Eurytomidae), *Habrocytus* sp. (Hymenoptera: Pteromalidae), *Hyssopus thymus* Girault (Hymenoptera: Eulophidae), the tachinid *Exeristes comstockii*, and an undetermined species were reared from European pine shoot moth. Individuals of the introduced *T. turionum*, *C. difformis*, and *P. turionellae* were also reared; however, no recoveries of *C. geniculatum*, *C. rufifemur* and *E. ruficollis* were made during the survey. Pointing and Green (1962) determined that the 21 native and introduced parasitoids had negligible impact on the host and only four, *O. obscurator*, *T. interruptor*, *P. turionellae* and *B. turionum*, of the 13 species introduced had established. Among these, *O. obscurator* was the most abundant in Ontario and Quebec.

Gypsy Moth, *Lymantria dispar* (L.) (Lepidoptera: Erebidae), was first reported in Ontario on Wolf Island near Kingston in 1969, spreading to the mainland and throughout eastern Ontario by 1971 (Griffiths 1977). A survey in 1974–1975 by Griffiths (1977) reported that among the four parasitoid species recovered, *Cotesia melanoscela*, *Compsilura concinnata* and *Parasetigena agilis* (Robineau-Desvoidy) (Diptera: Tachinidae) are exotic introductions, none of which targeted gypsy moth, while *Pimpla pedalis* Cresson (Hymenoptera: Ichneumonidae) is native. Also reported was the native *Gelis tenellus* as a hyperparasitoid of *C. melanoscela*. *Cotesia melanoscela* was the most widely distributed while *C. concinnata* was the most abundant. Nealis and Quednau (1996) documented releases and overwintering survival of the European *Ceranthia samarensis* (Villeneuve) (Diptera: Tachinidae) introduced for biological control of gypsy moth. Releases of gravid female adults, parasitized larvae and parasitized pupae were made from 1991–1996. In each year of release, evidence of successful parasitism by field-released females was observed. All progeny retrieved were in diapause and overwintering studies indicated that survival of pharate adults was expected to be high. Because of the low fecundity of *C. samarensis* ongoing monitoring was recommended to determine if successful establishment had occurred.

Imported Cabbageworm, *Pieris rapae* (L.) (Lepidoptera: Pieridae), was first reported in eastern Ontario in 1871 and throughout southwestern Ontario by 1876 (Harcourt 1963). Parasitoids are important mortality factors of *P. rapae* (Harcourt 1963), principally *Cotesia glomerata* (L.) (Hymenoptera: Braconidae) which attacks larvae. Later instars are attacked by *Phryxe vulgaris* (Fallén) (Diptera: Tachinidae) and pupae are attacked by *Pteromalus puparum* (L.) (Hymenoptera: Pteromalidae). Generalist species associated with *P. rapae* include *C. concinnata*, *Helicobia rapax* (Walker) (Diptera: Sarcophagidae) and *Madremyia saundersii* (Williston) (Diptera: Tachinidae). Although invertebrate predators and birds are present they did not have a significant impact, unlike granulosis virus which caused up to 94% mortality. Corrigan (1983) conducted a survey for *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) introduced from British Columbia as a biological control agent. Recovery of *C. rubecula* near Ottawa 10 years after its release indicated that this agent had established in eastern Canada and was tolerant of winter conditions. Up to 1982, no progeny of *C. rubecula* released near Guelph and Harrow in 1978–1979 were recovered in the years after release and it was thought that *C. rubecula* had been negatively impacted by hyperparasitoids. Carter and Laing (1997) reported on recoveries of a Chinese strain of *C. rubecula* released in 1991–1992. Three years after releases *C. rubecula* was

found in the release area, although the hyperparasitoids *Catolaccus* sp. (Hymenoptera: Pteromalidae), *Mesochorus vittator* (Zetterstedt) (Hymenoptera: Ichneumonidae) and *Baryscapus galactopus* (Ratzeburg) (Hymenoptera: Eulophidae) were reared from *C. rubecula* cocoons. Parasitism levels ranged from 15–21%.

Larch Casebearer, *Coleophora laricella* (Hübner) (Lepidoptera: Coleophoridae), was introduced into Ontario from 1935–1941. Graham (1958) studied the effectiveness of parasitoids of larch casebearer and confirmed establishment of *Chrysocharis laricinellae* (Ratzeburg) (Hymenoptera: Eulophidae) and *Agathis pumila* (Ratzeburg) (Hymenoptera: Braconidae). Parasitism by the widely established *A. pumila* ranged from 41% south of 43° north latitude to 67% between 44–45° north and it was present in areas of low and discontinuous host populations. In contrast, *C. laricinellae* had spread only 42 miles from the release point and spread appeared to be dependent on high host populations.

Oriental Fruit Moth, *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae), was first reported in Ontario in 1925 (McLeod 1962). Boyce and Dustan (1954) compared parasitism of *G. molesta* in a young peach orchard and a mature orchard, before and after pesticides (DDT and parathion) came into use. The most prevalent parasitoids recovered were the introduced *Macrocentrus ancylivora*, and the native *Hymenochaonia delicata*, *Enytus obliteratus* (Cresson), *Glypta rufiscutellaris* Cresson (Hymenoptera: Ichneumonidae) and *Temelucha minor*. Overall, *M. ancylivora* populations increased since insecticide use began while those of *G. rufiscutellaris* and *H. obliteratus* decreased. *Hymenochaonia delicata* a common parasite of the ragweed borer, *Epiblema strenuana* (Walker) (Lepidoptera: Tortricidae), continued to be abundant. Dustan and Boyce (1966) assessed parasitism of *G. molesta* from 1956–1965 and found that average parasitism by *M. ancylivora* was 43.2–64.5% in 1st and 2nd generations, respectively, in the Niagara region and 10.3 and 12.4% in the Essex county region. Parasitism of 2nd generation oriental fruit moth by *G. rufiscutellaris* was 1.4% in Niagara and 28.6% in Essex. Among the other parasitoids, *T. minor* was reared from larvae of the 1st and 2nd generations, and *Enytus obliteratus* (Cresson) (Hymenoptera: Ichneumonidae) and *H. delicata* were reared from larvae of the 1st generation. The abundance of *M. ancylivora* in the Niagara region was attributed to the presence of strawberry plantings which support populations of *Ancylis comptana* (Frölich) (Lepidoptera: Tortricidae), an alternate host of *M. ancylivora*. Phillips (1969) found that *M. ancylivora* was the most abundant of eight parasitoids reared from Oriental fruit moth in pear orchards. Between 40 and 50% of 1st and 2nd generation fruit moth larvae were parasitized from 1964–1966. In 1967, parasitism of 1st and 2nd generation fruit moth larvae increased to 61–74%, respectively, a positive response to increasing host numbers. Increased parasitism of 2nd generation larvae led to low adult emergence.

Pea Aphid, *Acyrthosiphon pisum* (Harris) (Hemiptera: Aphididae), an invasive species believed to be of Palaearctic-Oriental origin, was first reported in the Ottawa area about 1898 (Mackauer 1971). Mackauer and Bisdee (1965) reported on the status of *Aphidius smithi* Sharma and Subba Rao (Hymenoptera: Aphidiidae) introduced to control pea aphid. Their southern Ontario survey revealed *Praon pequodorum* Viereck and *Aphidius nigripes* Ashmead (Hymenoptera: Aphidiidae) to be the principal parasitoids of *A. pisum*, with *Praon* sp. and *Aphelinus semiflavus* Howard (Hymenoptera: Aphelinidae) of secondary importance. Although not released in Ontario, *A. smithii* was found in areas adjacent to

Lake Ontario and it was concluded that the populations present were the result of dispersal from releases made in the USA (New Jersey, Delaware, Pennsylvania) in the late 1950s.

Pear Psylla, *Cacopsylla pyricola* (Förster) (Hemiptera: Psyllidae), a European invader was first reported in Ontario in 1894 (McMullen 1971). Wilde (1965) studied the biology of *C. pyricola* and noted that the nymphal parasitoid *Trechnites insidiosus* (Crawford) (Hymenoptera: Encyrtidae) was abundant before the widespread use of insecticides came to dominate control strategies. However, the predators *Chrysopa* spp., *Hippodamia* sp., *Cycloneda* sp., *Ceratomegilla* sp., *Anthocoris* sp. and *Orius* sp. were abundant during the study period. *Anthocoris melanocerus* Reuter (Hemiptera: Anthocoridae) from British Columbia was released in southwestern Ontario (Wilde 1965). Philogene and Chang (1979) reported new records of parasitic chalcidoids of pear psylla in Ontario. *Trechnites insidiosus*, *Pachyneuron* sp. and *Coccidencyrtus* sp. were found for the first time parasitizing *C. pyricola*.

Potato Stem Borer, *Hydraecia micacea* (Esper) (Lepidoptera: Noctuidae), an invasive pest of European origin, established in southern Ontario in the 1960s, becoming a pest in eastern Ontario in 1968 (Deedat et al. 1983). West et al. (1984) studied the parasitoids of *H. micacea*, in southern Ontario and Europe. In Ontario, the tachinid *Lydella radicis* (Townsend) (Diptera: Tachinidae) was reared from 61% of the host larvae collected. Other parasitoids recovered were *Diadegma* sp., *Campoletis* sp., *Glypta* sp., and *Pterocormis* sp. and *Therion* sp. (Hymenoptera: Ichneumonidae), although parasitism levels were low (0.5–6%). European parasitoids imported into quarantine included *Lydella stabulans* (Meigen) (Diptera: Tachinidae), *Macrocentrus blandus* Eady and Clark (Hymenoptera: Braconidae), *Exephanes occupator* Gravenhorst (Hymenoptera: Ichneumonidae) and an unidentified mermithid nematode. Comparison of the biologies of *L. radicis* and *L. stabulens* suggested that these species may coexist in the field. *Lydella stabulens* has a lower developmental threshold (6.7°C) and develops faster (159 Degree days) than *L. radicis* (13.5 °C and 113 Degree days), suggesting that the latter species would attack overwintering potato stem borer larvae earlier in the season than the former species. Developmental studies of *M. blandus* suggested that it may require an alternate host in order to produce a 2nd generation in summer. Small numbers of *L. stabulans* and *M. blandus* were released near Guelph (43.7167°N 80.4000°W).

Red Clover Casebearer, *Coleophora deauratella* Lienig and Zeller (Lepidoptera: Coleophoridae), was discovered in Ontario in 1989 at New Liskard (Ellis and Bjornson 1996). This European native is a threat to red clover, *Trifolium pratense* L. (*Fabaceae*), seed crops. Ellis and Bjornson (1996) studied the biology and biological control of red clover casebearer. Based on a successful biological control program in New Zealand, individuals of the European native *Neochrysocharis formosus* (Westwood) (Hymenoptera: Eulophidae) were imported from the population established in New Zealand and released in Ontario. However, no recoveries of *N. formosa* were made, although several other parasitoids, including the native *Bracon pygmaeus* Provancher (Hymenoptera: Braconidae), were reared. There are some taxonomic issues relating to whether the New Zealand specimens released in Ontario were indeed *N. formosa*, known to be Holarctic, or a distinct more host-specific population of *N. formosa*, or the related European *N. trifolii* Erdös (Hymenoptera: Eulophidae).

6. Inundative Biological Control of Arthropods with Pathogens

Entomopathogens, like other natural enemies, are important agents for reducing populations of pest arthropods, particularly insects. Among these, *Bacillus thuringiensis* Berliner (Bacilliaceae) is the most studied and this is evident in the JESO publications summarized here. In addition, papers in JESO have evaluated several other entomopathogenic organisms for their potential for inundative biological of pest insects (Table 3).

Cameron (1952) conducted a review of diseases of insects to 1951. Included was information on the fungi, *Beauveria bassiana*, *Anisoplia austraca* Herbst, *Metarhizium anisopliae* (Metchnikoff) Sorokin (Clavicipitaeae), *Aspergillus flavus* Link (Trichocomaceae) and *Isaria larinosa* (Holmskiold) Fries (Moniliaceae), the bacteria *Enterobacter aerogenes* Hormaeche and Edwards, *Bacillus subtilis* (Ehrenberg), *B. proteus* (Bach), *B. thuringiensis*, and *Paenibacillus popilliae* Dutkey (Bacilliaceae), as well as polyhedroviruses and granuloviruses. The main conclusion was that better understanding of the biology and pathogenesis of the organisms should be a priority, before practical application as biopesticides could be considered. Later, Cameron (1969) reviewed the problems and prospects in the use of pathogens for insect control. He reported that *B. thuringiensis* and *B. papillae* were the most practical and most developed pathogens at the time. Other pathogens reported on in JESO include *Nosema* species (Microsporida), viruses, and pathogenic nematodes.

Bacillus thuringiensis. Angus and Heimpel (1960) reviewed the potential of bacteria for insect control. Among the several species mentioned, strains of *Bacillus thuringiensis* Berliner (*Bt*) were considered to be promising and the authors concluded that bacterial pathogens can be used to advantage in certain situations but they will never entirely replace chemical insecticides.

Angus (1965) studied the post-larval mortality of *Bt* on forest tent caterpillar, the Grey Midget, *Nycteola cinereana* Neumoegen and Dyar (Lepidoptera: Nolidae), and the Mourning Cloak, *Nymphalis antiopa* (L.) (Lepidoptera: Nymphalidae). Results showed that while most larvae were killed by *Bt* in the larval stage, some individuals of each species pupated; however, these did not survive and they contained *Bt* cells. Stewart et al. (1992) studied the factors affecting the efficacy of *Bt* serovar. *San Diego* against larvae of the Colorado potato beetle. They determined that young larvae are most susceptible and should be targeted when using this agent. Morris (1980) isolated microbial pathogens from the Maize Weevil, *Sitophilus zeamais* Motchulsky (Coleoptera: Curculionidae), including a *Bacillus* sp. from adults and two *Pseudomonas* spp. from larvae and pupae.

Tripp (1972) reported on field trials of *Bt* applications to control Eastern Spruce Budworm, *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae). Application rates of 3.6 and 4.0 billion International Units (BIU) / US gal / acre effected mortalities of 96–99% on balsam fir and 80–86% on white spruce 33 days after spraying, although the occurrence of frost shortly after spraying may have influenced mortality.

Cadogan et al. (1987) evaluated a formulation of *Bt* on Jack Pine Budworm, *Choristoneura pinus pinus* (Freeman) (Lepidoptera: Tortricidae). Futura®, a new *Bt* formulation effectively suppressed populations of *C. pinus pinus* and prevented serious defoliation of host tress when applied at a rate of 30 BIU/ha. Cadogan (1993) showed that

C. pinus pinus larvae that survived *Bt* applied at 30 BIU weighed significantly less than controls and *Bt* applied at 20 BIU, suggesting that weights of surviving larvae could be used as an additional criterion for assessing efficacy of *Bt*.

***Nosema* species** – Wilson (1978) determined that incidence of the microsporidian *Nosema fumiferanae* (Thompson) (Nosematidae) infections increased from 35.9–69.0% over a five-year period of outbreak of its host, eastern spruce budworm. Wilson (1981) looked at the effects of *N. fumiferanae* on rearing stock of this host. Synthetic diets allowed the host to cope better with infection by *N. fumiferana*. Wilson (1985a) studied transmission and effects of *N. fumiferanae* and *Pleistophora schubergi* Zwölfer (Pleistophoridae) on eastern spruce budworm. Males infected with either *N. fumiferanae* or *P. schubergi* did not transmit spores to uninfected females through mating. However, *P. schubergi* infection reduced pupal weight (about 30%) and adult longevity of females by 2.5 days. Wilson (1985b) studied dose mortality response of *P. schubergi* on eastern spruce budworm and found that a dose of 5 x 10^5 spores/larva caused >80% mortality of larvae and a dose of 5x10^7 spores/larva caused 100% mortality. Higher doses resulted in decreased survival times of infected larvae. Wilson (1987) found that *Vairimorpha necatrix* (Kramer) (Nosematidae) caused high mortality: a dose of 5 x 10^4 spores/needle caused 100% mortality. Large doses caused mortality by gut damage and bacterial septicemia, whereas low doses caused death by microsporidiosis usually just before pupation.

Wilson and Burke (1979) documented the presence of three microsporidians, *Nosema cerasivoranus* Thomson (Nosematidae), *Pleistophora* sp. (Pleistophoridae) and *Thelohania* sp. (Thelohaniidae) from larvae of the Ugly Nest Caterpillar, *Archips cerasivoranus* (Fitch) (Lepidoptera: Tortricidae). Levels of parasitism varied between years and among species, *Pleistophora* sp. at 3–35.9% was the most prevalent, followed by *N. cerasivoranae* at 0–28%, and *Thelohania* at 0–2.3%. Wilson (1980) examined the effects of *Nosema disstriae* Thompson (Nosematidae) on the forest tent caterpillar, *M. disstria*, finding that this microsporidian adversely affected pupal weights, adult fecundity and longevity.

Laing and Jaques (1985) studied Microsporidia associated with the European Corn Borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae) over a 7-year period. Applications of *Nosema pyrausta* (Paillot) (Nosematidae), *V. necatrix*, *Bt* and *Autographa californica* nuclear polyhedrosis virus (ACNPV) (*Baculoviridae*) had little or no effect on reducing crop damage compared to insecticides. However, Microsporidia infection levels of field collected corn borer larvae (17–40%) and adults (10–24%) did not result in reduced damage to the current crop but these authors concluded that infection levels may, over the longer term, reduce viability of populations of the pest.

Viruses – Cunningham et al. (1987) found the nuclear polyhedrosis virus *Lecontvirus* (*Baculoviridae*) to be highly effective against the Redheaded Pine Sawfly, *Neodiprion lecontei* (Fitch) (Hymenoptera: Tenthredinidae). A dose of 5 x 10^9 polyhedral inclusion bodies (PIB) per ha in spray volumes of 2.4–9.4 L/ha provided consistent control when applied to 1st–3rd instar larvae. The virus can be cheaply produced (50 infected larvae can produce enough concentrate for the 5 x 10^9 PIB/ha dose) at about $2.50/ha in 1985 dollars and applied using water alone. Evaluation of 100 trees, each with one redheaded pine sawfly colony and scoring colonies as healthy, diseased or dead, allowed reliable monitoring of epizootic progress. It was registered in Canada and was being used by Ontario.

Jaques (1971) studied the potential for use of viruses to control cabbage insect pests. Natural epizootics of the nuclear polyhedrosis viruses, *Tricoplusia ni NPV* (TnNPV) and *Pieris rapae GV* (PrGV) (*Baculoviridae*) contributed substantially to control of *T. ni* and *P. rapae* in the latter part of the season. Natural epizootics were the result of virus accumulations in the soil, TnNPV residues being found in 60% and *P. rapae* GV in 19% of samples taken. Application of the viruses to plants resulted in control as effective as or better than that provided by chemical pesticides.

Bird et al. (1973) studied the possible use of a *nuclear polyhedrosis virus* (NPV) and *entomopoxvirus* (EPV) (*Poxyviridae*) to control eastern spruce budworm. Both viruses were isolated from eastern spruce budworm and the Two-year-cycle Budworm, *Choristoneura biennis* Freeman (Lepidoptera: Tortricidae) from British Columbia. EPV was more effective on white spruce than on balsam fir in early season applications, while late spray of NPV was more effective. Virus carryover from 1971–1972 occurred.

Cunningham et al. (1996a) evaluated *Disparvirus*, nuclear polyhedrosis virus, and *Bt* serovar. *kurstaki* (*Btk*) applied as aerial sprays on mortality of gypsy moth. Average egg mass reductions from *Disparvirus* were 76% and 80% at a rates of 5.0 and 2.5 L/ha, respectively, and 96% for *Btk* at 50 billion International Units (BIU) in 4.0 L/ha. Cunningham et al. (1996b) reported on impact of *Disparvirus* and *Btk* one year after application. Gypsy moth, larvae were 20.4% positive for NPV in plots treated with *Disparvirus* at 5.0 L/ha, 14.6% positive for NPV in plots treated at 2.5 L/ha, and 8.0% positive for NPV in plots treated with *Btk*, and 9.2% positive for NPV in control plots. Negligible foliage damage was reported and fall egg mass numbers were low indicating that in the treated area, the gypsy moth population had collapsed, suggesting that NPV was a contributing factor.

Nematodes – Welch (1962) reviewed the status of nematodes as agents for insect control. In nature, nematodes are generally not significant mortality factors, although under some conditions they may be significant regulatory factors. Mermithidae have the greatest potential as biological control agents because of their size and similarity to insect parasitoids. Neoaplectanidae also show potential because of their high rate of reproduction. Allantonematidae and Aphelenchoidea are best suited to environmental manipulation. Moisture, moderate temperatures and high host density are important factors for successful control.

Welch and Briand (1962) evaluated a neoplectanid nematode for control of Colorado potato beetle, cabbage root maggot, European corn borer and the imported cabbage worm. Use of the nematode was most promising for control of cabbage root maggot and European corn borer where the soil environment provides conditions suitable for nematode survival.

Briand (1960) reported the occurrence of the nematode *Howardula beninga* Cobb (Tylenchida: Allantonematidae) in the Striped Cucumber Beetle, *Diabrotica vittata* (Fabricius) (Coleoptera: Chrysomelidae). Parasitism was 7.6% and 2.5% in surveys conducted in 1958 and 1959, respectively. Parasitism was nil in the secondary host *D. unidecimpunctata howardi* (Barber) even though this species was common in the southern Ontario study area.

Wright (1972) reported a new Canadian record for the adventive nematode *Heterotylenchus autumnalis* Nickle (Nematoda: Sphaerulariidae) as a parasite of the Face Fly, *Musca autumnalis* DeGeer (Diptera: Muscidae). *Heterotylenchus autumnalis* is widely distributed in Ontario but incidence was <2% and unlikely to contribute significantly to

natural control. Gregory and Wright (1973) released irradiated female face flies parasitized with *H. autumnalis* and found that doses of 1.0 and 2.5 krad did not sterilize the nematodes and parasitized face fly females produced progeny with high levels of parasitism. Release of sterile flies that were parasitized was considered better than the release of sterile flies alone.

Welch (1958) evaluated the nematode *Neaplectana chresima* Steiner (Rhabdidita: Steinernematidae) for biological control of Colorado potato beetle. Application of ~20,000 cultured nematodes resulted in an approximate 14% reduction in beetle numbers although abiotic factors, i.e., significant rainfall, had an impact on the nematodes.

7. Natural Enemy Taxonomy

Taxonomy is essential to biological control and a few studies on groups relevant to biological control have been published in JESO. These studies, while clarifying taxonomic status, unfortunately also demonstrate just how poorly the biology of parasitoids is understood. Six taxonomic studies published in JESO that are relevant to biological control treat taxa within the Hymenoptera familes Braconidae (2), Eucharitidae (1) and Mymaridae (3).

Braconidae. Loan (1970) described the new species, *Leiophron pseudopallipes* Loan and *Leiophron lygivora* (Loan) (Hymenoptera: Braconidae) reared from tarnished plant bug, *Lygus lineolaris*, in Ontario. *Leiophron pseudopallipes* is ecologically distinct, attacking 2nd generation *L. lineolaris*, from the related *L. mellipes* (Cresson) which attacks the 1st generation. *Leiophron lygivora* also attacks 2nd generation *L. lineolaris*. Loan and New (1972) reviewed the taxonomy of the Euphorine (Hymenoptera: Braconidae) genus *Leiophron*, subgenus *Euphoriella* Ashmead and redescribed *L.* (*E.*) *sommermanae* (Muesebeck), *L.* (*E.*) *incerta* (Ashmead), and *L.* (*E.*) *pacifica* (Muesebeck). *Leiophron* (*E.*) *nixoni* (Loan and New), *L.* (*E.*) *kaladarensis* (Loan and New), *L.* (*E.*) *solidaginis* (Loan and New), *L.* (*E.*) *foutsi* (Loan and New), *L.* (*E.*) *pallidifacia* (Loan and New), *L.* (*E.*) *hyalopsocidis* (Loan and New) and *L.* (*E.*) *criddlei* (Loan and New) were newly described. *Leiophron* (*E.*) *hyalopsocidis* was the only species associated with a host and it was reared from the psocid *Hyalopsocus striatus* (Walker) (Psocoptera: Psocidae).

Sharkey (2007) revised the Neotropical Braconidae (Hymenoptera) genus *Trachagathis* Viereck. Among the 3 species treated, *Trachagathis rubricincta* (Ashmead) is associated with the lesser cornstalk borer, *Elasmopalpus lingosellus* (Zeller) (Lepidoptera: Pyralidae), from sugarcane and the biologies of the other two species are unknown.

Eucharitidae. Heraty (1985) revised the Nearctic Eucharitinae (Hymenoptera: Eucharitidae), providing keys to the 5 genera and 16 species. Species of Eucharitidae are specialized ant parasitoids. Among the species treated, only the host of *Pseudometagea schwarzii* (Ashmead), the ant *Lasius neoniger* Emery (Hymenoptera: Formicidae), is known.

Mymaridae. Huber (1992) studied the subgenera and species groups of *Anaphes* (Hymenoptera: Mymaridae), and reviewed the described Nearctic species of the *fuscipennis* group of *Anaphes s.s.* and the described species of *Anaphes* (*Yungaburra*). *Anaphes* spp. are mostly parasitoids of Curculionidae and Chrysomelidae. Among the 9 species of the *Anaphes fuscipennis* group treated, hosts have been associated with *Anaphes fuscipennis* Haliday [*Sitona humeralis* Stephens, *Hypera postica* (Gyllenhal) and *H. punctata*

(Fabricius) (Coleoptera: Curculionidae)], *A. iole* Girault [*Lygus* spp. and *Pseudatomoscelis* sp. (Hemiptera: Miridae)], *A. byrrhidiphagus* Huber [*Lioon simplicipes* (Mannerheim) and *Lioligus nitidus* (Motschulsky) (Coleoptera: Byrridae)], and *Anaphes flavipes* (Förster) [*Oulema melanopus* (L.), *O. gallaeciana* (Heydon), *O. collaris* (Say), *Lema trilineata* Oliver, *L. trilineata trivittata* (Say), *L. lichenis* Voet. and *L. cyanella* (L.) (Coleoptera: Chrysomelidae)]. *Anaphes flavipes* was imported for biological control of *O. melanopus*. Hosts are unknown for the six species of the *Anaphes* (*Yungabura*) group.

Huber (2006) reviewed the described species of the *Anaphes crassicornis* group, important in biological control with the aim to improve identification of the species. Among the 13 species treated hosts are known for *Anaphes calendrae* (Gahan) [*Sphenophorus* spp. (Coleoptera: Curculionidae)], *A. conotracheli* Girault [*Conotrachelus geminatus* (LeConte), *Hypera nigrirostris* (Fabricius) (Coleoptera: Curculionidae)], *A. cotei* Huber [*Listronotus oregonensis* (LeConte) (Coleoptera: Curculionidae)], *A. diana* (Girault) [*Sitona hispidulus* (Fabricius), *S. humeralis* Stephens, *S. lineatus* (L.) (Coleoptera: Curculionidae)], *A. gerrisophagus* (Doutt) [*Gerris* sp. (Hemiptera: Gerridae) and *Lestes* sp. (Odonata: Lestidae)], *A. listronoti* Huber [*L. oregonensis*], *A. luna* (Girault) [*Hypera* spp., and in North America, *H. postica* (Gyllenhal) and *H. eximia* (LeConte) (Coleoptera: Curculionidae)], *A. pallipes* (Ashmead) [*Cylindrocopturus adspersus* (LeConte) (Coleoptera: Curculionidae) and *Rhagoletis pomonella* Walsh (Diptera: Tephritidae)], *A. pullicrurus* (Girault) [*Chaetoctema denticulata* (Illiger) (Coleoptera: Chrysomelidae)], *A. sordidatus* [*Tyloderma foveolatum* (Say) (Coleoptera: Curculionidae)], and *A. victus* Huber [*L. oregonensis*]. *Anaphes luna* and *A. diana* were imported and released in the USA as biological control agents.

Huber (2012) revised the *Ooctonus* spp. (Hymenoptera: Mymaridae) in the Nearctic region. Among the 15 species described, hosts are known for *O. aphrophorae* Milliron [on *Aphrophora saratogensis* (Fitch) (Hemiptera: Cercopidae)], and *O. vulgatus* Haliday [on *Philaenus spumarius* (L.) (Hemiptera: Cercopidae)]. Although white pine weevil was recorded as a potential host for *O. quadricarinatus* Girault the record is incorrect (J. Huber, personal communication).

Conclusions

Over the years, the *Journal of the Entomological Society of Ontario* has been an important venue for dissemination of scientific results on biological control of pest arthropods and weeds in Ontario. Included are studies on natural enemy assemblages, biology of natural enemies, releases of exotic species as agents for biological control, entomopathogens for use in reduced risk management strategies, and taxonomy of groups important to biological control. In recent years, competition with an ever increasing number of specialized journals with high impact factors, many of which have no page charges, has led to a decline in submissions to JESO. However, there are unfilled niches for which JESO can provide a good opportunity to publish: documenting the status and distribution of natural enemies intentionally released as biological control agents, documenting associations among natural enemies and hosts, and assessing changes in natural enemy assemblages over time.

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References

Abu, J. F. and Ellis, C. R. 1976. Biology of *Bathyplectes curculionis* (Thomson) (Hymenoptera: Ichneumonidae) a parasitoid of the alfalfa weevil in Ontario. *Proceedings of the Entomological Society of Ontario* **106**: 8–12.

Alex, J. F. 1998. Ontario Weeds. Ontario weeds: descriptions, illustrations and keys to their identification. Ontario Ministry of Agriculture, Food and Rural Affairs Publication 505, Guelph, Ontario, Canada. Available from http://www.omafra.gov.on.ca/english/crops/pub505/p505order.htm [Accessed 1 November 2013].

Angus, T. A. and Heimpel, A. M. 1960. The bacteriological control of insects. *Proceedings of the Entomological Society of Ontario* **90**: 13–21.

Angus, T. A. 1965. Mortality due to *Bacillus thuringiensis* in post-larval stages of some Lepidoptera. *Proceedings of the Entomological Society of Ontario* **95**: 133–134.

Anonymous. 2012. Noxious weeds in Ontario. Available at: http://www.omafra.gov.on.ca/english/crops/facts/noxious_weeds.htm [Accessed 1 November 2013].

Appleton, E. S. B., Gillard, C. and Schaafsma, A. W. 2004. Biology and management of the potato leafhopper, *Empoasca fabae* Harris (Homoptera: Cicadellidae) on field crops in Ontario. *Journal of the Entomological Society of Ontario* **134**: 3–17.

Bahlai, C. A. and Sears, M. K. 2009 Population dynamics of *Harmonia axyridis* and *Aphis glycines* in Niagara peninsula soybean fields and vineyards. *Journal of the Entomological Society of Ontario* **140**: 27–39.

Beirne, B. P. 1971. Pest insects of annual crop plants in Canada: Part I, Lepidoptera; II, Diptera; III, Coleoptera. *Memoirs of the Entomological Society of Canada 103, Supplement* **S78**: 1–124.

Bennett, A. M. R. 2004. Host location behaviour in *Pelecinus polyturator* (Hymenoptera: Pelecinidae). *Journal of the Entomological Society of Ontario* **135**: 131–134.

Ben-Ze'ev, L. S. and Jaques, R. P. 1990. Entomopathogenic fungi in insects in alfalfa fields in southwestern Ontario. *Proceedings of the Entomological Society of Ontario* **121**: 71–78.

Best, K. F., Bowes, G. G., Thomas, A. G. and Maw, M. G. 1980. The biology of Canadian weeds. 39. *Euphorbia esula* L. *Canadian Journal of Plant Science* **60**: 651–663.

Bird, F. T., Cunningham, J. S. and Howse, G. M. 1973. The possible use of viruses in the control of spruce budworm. *Proceedings of the Entomological Society of Ontario* **102**: 69–75.

Bolter, C. J. and Laing J. E. 1984. Competition between *Diadegma insulare* (Hymenoptera: Ichenumonidae) and *Microplitis plutellae* (Hymenoptera: Braconidae) for larvae of the diamonback moth, *Plutella xylostella* (Lepidoptera: Plutellidae). *Proceedings of the Entomological Society of Ontario* **114**: 1–10.

Briand, L. J. 1960. The nematode *Howardula benigna* Cobb, 1921, parasite of the cucumber beetles in Ontario. *Proceedings of the Entomological Society of Ontario* **90**: 53.

Bright, D. E. 1996. Notes on native parasitoids and predators of the larger pine shoot beetle, *Tomicus piniperda* (Linnaeus) in the Niagara region of Canada (Coleoptera: Scolytidae). *Proceedings of the Entomological Society of Ontario* **127**: 57–62.

Broadbent, A. B., Goulet, H., Whistlecraft, J. W., Lachance, S. and Mason, P. G. 1999. First Canadian record of three parasitoid species (Hymenoptera: Braconidae: Euphorinae) of the tarnished plant bug, *Lygus lineolaris* (Hemiptera: Miridae). *Proceedings of the Entomological Society of Ontario* **130**: 109–111.

Broadbent, A. B., Haye, T., Gariepy, T. D., Olfert, O. O. and Kuhlmann, U. 2013. *Lygus lineolaris* (Palisot), tarnished plant bug (Hemiptera: Miridae). Pp. 221–227 *in* Mason P. G. and Gillespie, D. R. (eds), *Biological Control Programmes in Canada 2001–2012*. CABI Publishing, Wallingford, Oxfordshire United Kingdom, 518 pp.

Boyce, H. R. and Dustan, G. G. 1954. Parasitism of twig-infesting larvae of the oriental fruit moth, *Grapholita molesta* (Busck) (Lepidoptera: Olethreutidae), in Ontario, 1939–1953. *Annual Report of the Entomological Society of Ontario* **84**: 48–55.

Cadogan, B. L. 1993. Field weights of jack pine budworm larvae (Lepidoptera: Tortricidae) surviving aerial applications of *Bacillus thuringiensis* and two chemical insecticides. *Proceedings of the Entomological Society of Ontario* **124**:189–196.

Cadogan, B. L. and Laing, J. E. 1982. A study of *Balaustium putnami* (Acarina: Erythraeidae) in apple orchards in southern Ontario. *Proceedings of the Entomological Society of Ontario* **112**: 13–21.

Cadogan, B. L., Zylstra, B. F., Nystrom, C., Ebling, P. M. and Pollock, L. B. 1987. Evaluation of a new Futura® formulation of *Bacillus thuringiensis* on populations of jack pine budworm, *Choristoneura pinus pinus* (Lepidoptera: Tortricidae). *Proceedings of the Entomological Society of Ontario* **117**: 59–64.

Cameron, J. W. M. 1952. A survey of investigations on the diseases of insects. *Annual Report of the Entomological Society of Ontario* **83**: 7–14.

Cameron, J. W. M. 1969. Problems and prospects in the use of pathogens in insect control. *Proceedings of the Entomological Society of Ontario* **99**: 73–81.

Carter, N. J. and Laing, J. E. 1997. *Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae) recovered three years after release in southern Ontario. *Proceedings of the Entomological Society of Ontario* **128**: 113–115.

Chant, D. A.1957. Biological control. *Annual Report of the Entomological Society of Ontario* **87**: 54–58.

Clements, D. R. 1989. The role of stigmaeids (Acari) in the orchard acarine system. *Proceedings of the Entomological Society of Ontario* **120**: 74–75.

Coote, L. D. and Ellis C. R. 1987. Parasites of the alfalfa blotch leafminer, *Agromyza frontella* (Diptera: Agromyzidae), near Guelph, Ontario. *Proceedings of the Entomological Society of Ontario* **117**: 21–27.

Coote, L. D. and Ellis, C. R. 1987. *Diglyphus intermedius* (Hymenoptera: Eulophidae), in indigenous parasite of the alfalfa blotch leafminer, *Agromyza frontella* (Diptera: Agromyzidae). *Proceedings of the Entomological Society of Ontario* **117**: 83–85.

Coppel, H. C. and Arthur, A. P. 1954. Notes on introduced parasites of the European pine shoot moth, *Rhyacionia buliana* (Schiff.) (Lepidoptera: Tortricidae), in Ontario. *Annual Report of the Entomological Society of Ontario* **84**: 55–58.

Corrigan, J. E. 1983. *Cotesia* (*Apanteles*) *rubecula* (Hymenoptera: Braconidae) recovered in Ottawa, Ontario ten years after its release. *Proceedings of the Entomological Society of Ontario* **113**: 71.

Corrigan, J. E. and Laing, J. E. 1992. An improved method for producing small, consistent samples of hosts for presentation to the egg parasitoid, *Trichogramma minutum*. *Proceedings of the Entomological Society of Ontario* **122**: 103-104.

Corrigan, J. E., Lashomb, J. H. and Kingsley, P. C. 1990. Pupal orientation and emergence success of the egg parasitoids *Edovum puttleri* (Hymenoptera: Eulophidae). *Proceedings of the Entomological Society of Ontario* **121**: 95–100.

Corrigan, J. E., Laing, J. E. and Caddick, G. 1994. Feasibility of delaying emergence of *Trichogramma minutum* Riley (Hymenoptera: Trichogrammatidae) and subsequent effects on adult longevity and fecundity. *Proceedings of the Entomological Society of Ontario* **125**: 81–86.

Corrigan, J. E., Mackenzie, D. L. and Simser, L. 1998. Field observations of non-target feeding by *Galerucella calmariensis* [Coleoptera: Chrysomelidae], an introduced biological control agent of purple loosestrife, *Lythrum salicaria* [Lythraceae]. *Proceedings of the Entomological Society of Ontario* **129**: 99–106.

Crompton, C. W., Hall, I. V., Jensen, K. I. N. and Hildebrand, P. D. 1988. The biology of Canadian weeds. 83. *Hypericum perforatum* L. *Canadian Journal of Plant Science* **68**: 149–162.

Cunningham, J. C., deGroot, P. and Kaup, W. J. 1987. A review of aerial spray trials with Lecontvirus for control of redhead pine sawfly, *Neodiprion lecontei* (Hymenoptera: Diprionidae), in Ontario. *Proceedings of the Entomological Society of Ontario* **117**: 65–72.

Cunningham, J. C., Payne, N. J., Brown, K. W., Fleming, R. A., Burns, T., Mickle, R. E. and Scarr, T. 1996a. Aerial spray trials with nuclear polyhedrosis virus and *Bacillus thuringiensis* on gypsy moth (Lepidoptera: Lymantriidae) in 1994. I. Impact in the year of application. *Proceedings of the Entomological Society of Ontario* **127**: 21–35.

Cunningham, J. C., Brown, K. W., Scarr, T., Fleming, R. A. and Burns, T. 1996b. Aerial spray trials with nuclear polyhedrosis virus and *Bacillus thuringiensis* on gypsy moth (Lepidoptera: Lymantriidae) in 1994. II. Impact one year after application. *Proceedings of the Entomological Society of Ontario* **127**: 37–43.

Deedat, Y. D., Ellis, C. R. and West, R. J. 1983. Life History of the Potato Stem Borer (Lepidoptera: Noctuidae) in Ontario. *Journal of Economic Entomology* **76**: 1033–1037.

Desrochers, A. M., Bain, J. F. and Warwick, S. I. 1988. The Biology of Canadian weeds. 89. *Carduus nutans* L. and *Carduus acanthoides* L. *Canadian Journal of Plant Science* **68**: 1053–1068.

Dustan, G. G. and Boyce, H. R. 1966. Parasitism of the oriental fruit moth, *Grapholitha molesta* (Busck) (Lepidoptera: Tortricidae) in Ontario, 1956–1965. *Proceedings of the Entomological Society of Ontario* **96**: 100–102.

Edwards, C. J. and Pengelly, D. H. 1966. *Melittobia chalybii* Ashmead (Hymenoptera: Eulophidae) parasitizing *Bombus fervidus* Fabricius (Hymenoptera Apidae). *Proceedings of the Entomological Society of Ontario* **96**: 98–99.

Ellis, C. R., Harcourt, D. G. and Dubois-Martin, D. 1979. The current status in Ontario of *Tetrastichus julis* (Hymenoptera: Eulophidae), a parasitoid of the cereal leaf beetle. *Proceedings of the Entomological Society of Ontario* **109**: 23–26.

Ellis, C. R., Kormos, B. and Guppy, J. C. 1989. Absence of parasitism in an outbreak of the cereal leaf beetle, *Oulema melanopus* (Coleoptera: Chrysomelidae), in the central tobacco growing area of Ontario. *Proceedings of the Entomological Society of Ontario* **119**: 43–46.

Ellis, C. R. and Nang'ayo, F. L. O. 1992. The biology and control of the trefoil seed chalcid, *Bruchopagus platypterus* (Walker) (Hymenoptera: Eurytomidae), in Ontario. *Proceedings of the Entomological Society of Ontario* **123**: 111–122.

Ellis, C. R. and Bjornson, S. 1996. The biology, importance, and biological control of *Coleophora deauratella* (Lepidoptera: Coleophoridae), a new pest of red clover in North America. *Proceedings of the Entomological Society of Ontario* **127**: 115–124.

Fisher, P. 1988. The effect of pesticides on two species of parasitoids, *Pholetesor ornigis* and *Pholetesor pedias* (Hymenoptera: Braconidae). *Proceedings of the Entomological Society of Ontario* **118**: 171.

Foott, W. H. 1974. Observations on Coccinellidae in corn fields in Essex County, Ontario. *Proceedings of the Entomological Society of Ontario* **104**: 16–21.

George, J. A. 1979. The potential of a local planarian, *Dugesia tigrina* (Tricladida, Turbellaria), for the control of mosquitoes in Ontario. *Proceedings of the Entomological Society of Ontario* **109**: 23.

George, J. A. 1984. Survival of the mosquito predator *Dugesis tigrina* (Tricladida: Turbellaria), over three years in catch basins. *Proceedings of the Entomological Society of Ontario* **114**: 83–85.

Glen, R. 1962. Preface. Pp. ix–x *in* McLeod, J. S., McGugan, B. M. and Coppel, H. C. (eds), *A review of the biological control attempts against insects and weeds in Canada.* Technical Communication Commonwealth Institute of Biological Control 2, Franham Royal, Bucks, England, 216 pp.

Glen, R. 1965. Entomology in Canada up to 1956. A review of developments and accomplishments. *The Canadian Entomologist* **58**: 290–371.

Goble, H. W. 1965. The armyworm *Pseudaletia unipuncta* (Hawthorn) in Ontario in 1964. *Proceedings of the Entomological Society of Ontario* **95**: 11–14.

Graham, A. R. 1958. Effectiveness of two introduced parasites of the larch casebearer, *Coleophora laricella* (Hbn.) (Lepidoptera: Coleophoridae), in Ontario. *Annual Report of the Entomological Society of Ontario* **88**: 37–41.

Gregory, D. and Wright, R. E. 1973. Irradiation of the female face fly, *Musca autumnalis* DeGeer, parasitized by the nematode, *Heterotylenchus autumnalis* Nickle. *Proceedings of the Entomological Society of Ontario* **102**: 104–107.

Griffiths, K. J. 1972. Discrimination between parasitized and unparasitized hosts by *Pleolophus basizonus* (Hymenoptera: Ichneumonidae). *Proceedings of the Entomological Society of Ontario* **102**: 83–91.

Griffiths, K. J. 1977. A preliminary report on the gypsy moth and its parasites in southeastern Ontario. *Proceedings of the Entomological Society of Ontario* **107**: 79–84.

Hagley, E. A. C. 1970. The distribution and survival of overwintering codling moth larvae in southern Ontario. *Proceedings of the Entomological Society of Ontario* **100**: 40–47.

Hagley, E. A. C. 1979. Integrated pest management — insecticides and natural predator populations on apple. *Proceedings of the Entomological Society of Ontario* **109**: 9–21.

Hagley, E. A. C. 1987. Occurrence of *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) in apple orchards in southern Ontario. *Proceedings of the Entomological Society of Ontario* **117**: 79–82.

Hagley, E. A. C. and Barber, D. R. 1992. Foliage-feeding Lepidoptera and their parasites recovered from unmanaged apple orchards in southern Ontario. *Proceedings of the Entomological Society of Ontario* **122**: 1–7.

Hagley, E. A. C. and Laing, J. E. 1989. Effect of pesticides on parasitism of artificially distributed eggs of the codling moth, *Cydia pomonella* (Lepidoptera: Tortricidae). *Proceedings of the Entomological Society of Ontario* **120**: 25–33.

Harcourt, D. G. 1963. Biology of cabbage caterpillars in eastern Ontario. *Proceedings of the Entomological Society of Ontario* **93**: 61–75.

Harcourt, D. G. and Ellis, C. R. 1992. Distribution in southern Ontario of *Bathyplectes anurus* (Hymenoptera: Ichneumonidae), a larval parasitoid of the alfalfa weevil. *Proceedings of the Entomological Society of Ontario* **122**: 41–45.

Harcourt, D. G., Ellis, C. R. and Guppy, J. C. 1980. Distribution of *Microctonus aethiopoides*, a parasitoid of the alfalfa weevil (Coleoptera: Curculionidae) in Ontario. *Proceedings of the Entomological Society of Ontario* **110**: 35–39.

Harcourt, D. G., Guppy, J. C. and Ellis, C. R. 1982. Distribution of *Microctonus colesi* (Hymenoptera: Braconidae), a new parasite of the alfalfa weevil in Ontario. *Proceedings of the Entomological Society of Ontario* **112**: 33–37.

Harcourt, D. G., Guppy, J. C. and Ellis C. R. 1987. Establishment and spread of *Dacnusa dryas* (Hymenoptera: Braconidae), an exotic parasite of the alfalfa blotch leafminer in Ontario. *Proceedings of the Entomological Society of Ontario* **117**: 29–33.

Harmsen, R. and Rose, M. R. 1984. Habitat effects on larval mortality in the forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae). *Proceedings of the Entomological Society of Ontario* **114**: 87–89.

Heraty, J. M. 1985. A revision of the Nearctic Eucharitinae (Hymenoptera: Chalcidoidea: Eucharitidae). *Proceedings of the Entomological Society of Ontario* **116**: 61–103.

Herbert, H. J. 1953. Progress report on predacious mite investigations in Nova Scotia (Acarina: Phytoseiidae). *Annual Report of the Entomological Society of Ontario* **84**: 27–29.

Hikichi, A. 1962. Notes on mortality factors affecting the red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.), (Lepidoptera: Tortricidae) in an unsprayed apple orchard in Ontario. *Proceedings of the Entomological Society of Ontario* **92**: 180–182.

Hikichi, A. 1971. 3. *Argyrotaenia velutinana* (Walker), red-banded leafroller (Lepidoptera: Tortricidae). Pp. 10–12 *in* Kelleher et al. (eds), *Biological control programmes against insects and weeds in Canada 1959–1968*. Technical Communication Commonwealth Institute of Biological Control 4, 266 pp.

Hoffmeister T. S. 2002. *Rhagoletis pomonella* (Walsh), apple maggot (Diptera: Tephritidae). Pp. 238–241 *in* Mason, P. G. and Huber, J. T. (eds), *Biological Control Programmes in Canada 1981–2000*. CABI Publishing, Wallingford, Oxon, United Kingdom, 583 pp.

Huber, J. T. 1992. The subgenera, species groups, and synonyms of *Anaphes* (Hymenoptera: Mymaridae) with a review of the described Nearctic species of the *fuscipennis* group of *Anaphes s.s.* and the described species of *Anaphes* (*Yungaburra*). *Proceedings of the Entomological Society of Ontario* **123**: 23–110.

Huber, J. T. 2006.Review of the described Nearctic species of the *crassicornis* group of *Anaphes s.s.* (Hymenoptera: Mymaridae). *Journal of the Entomological Society of Ontario* **135**: 3–86.

Huber, J. T. 2012. Revision of the genus *Ooctonus* (Hymenoptera: Mymaridae) in the Nearctic region. *Journal of the Entomological Society of Ontario* **143**: 15–105.

Hulme, M. A. and Kenis, M. 2002. *Pissodes strobe* (Peck), white pine weevil (Coleoptera: Curculionidae). Pp. 221–228 *in* Mason, P. G. and Huber, J. T. (eds), *Biological Control Programmes in Canada 1981–2002*. CABI Publishing, Wallingford, Oxon, United Kingdom, 583 pp.

Jaques, R. P. 1971. Control of cabbage insects by viruses. *Proceedings of the Entomological Society of Ontario* **101**: 28–34.

James, H. G. 1952. Natural control of Tabanidae (Diptera) in the region of Churchill, Manitoba. *Annual Report of the Entomological Society of Ontario* **83**: 70–74.

James, H. G. 1959. Egg development, hatching, and prey taken by the European mantis, *Mantis religiosa* L., in several habitats. *Annual Report of the Entomological Society of Ontario* **89**: 50–55.

Jones, T., Shipp, J. L., Scott-Dupree, C. D. and Harris, C. R. 2006. Influence of greenhouse microclimate on *Neoseiulus (Amblyseius) cucumeris* (Acari: Phytoseiidae) predation on *Frankliniella occidentalis* (Thysanoptera: Thripidae) and oviposition on greenhouse cucumber. *Journal of the Entomological Society of Ontario* **136**: 71–83.

Johnson, E. F., Laing, J. E. and Trottier, R. 1977. The seasonal occurrence of *Lithocolletis blancardella* (Gracillariidae), and its major natural enemies in Ontario apple orchards. *Proceedings of the Entomological Society of Ontario* **107**: 31–45.

Judd, W. W. 1953. Diptera and Hymenoptera reared from pine cone willow galls caused by *Rhabdophaga strobiloides* (Diptera: Itonididae). *Annual Report of the Entomological Society of Ontario* **84**: 34–42.

Kelleher, J. S. et al. 1971. *Biological control programmes against insects and weeds in Canada 1959–1968*. Technical Communication Commonwealth Institute of Biological Control 4, Franham Royal, Slough, England, 266 pp.

Kelleher, J. S. and Hulme, M. A. (eds) 1984. *Biological Control Programmes agains insects and weeds in Canada 1969–1980*. Commonwealth Agricultural Bureaux, Franham Royal, Slough, England, 410 pp.

Laing, J. E. 1978. Establishment of *Urophora cardui* L. (Diptera: Tephritidae) on Canada thistles in southern Ontario. *Proceedings of the Entomological Society of Ontario* **108**: 2.

Laing, D. R. and Jaques, R. P. 1985. Microsporidia of the European corn borer (Lepidoptera: Pyralidae) in southwestern Ontario: natural occurrence and effectiveness as microbial insecticides. *Proceedings of the Entomological Society of Ontario* **115**: 13–17.

Laing, J. E. and Welch, H. E. 1963. A dolichopodid predacious on larvae of *Culex restuans* Theob. *Proceedings of the Entomological Society of Ontario* **93**: 89–90.

Laing, J. E. and Heraty, J. M. 1982. The parasite complex of the overwintering population of *Epiblema scudderiana* (Lepidoptera: Olethreutidae) in southern Ontario. *Proceedings of the Entomological Society of Ontario* **112**: 59–66.

Laing, J. E. and Heels, P. R. 1979. Establishment of an introduced weevil, *Rhinocyllus conicus* (Coleoptera: Curculionidae) for the biological control of nodding thistle, *Carduus nutans* (Compositae) in southern Ontario. *Proceedings of the Entomological Society of Ontario* **109**: 3–8.

LeSage L. 1989. Survival of *Aphthona* species in Ontario. *Biocontrol News* **2**: 1.

LeSage, L. 1996a. Suivi, pour les années 1994 et 1995, des altises de l'euphorbe (Coleoptera: Chrysomelidae: *Aphthona* spp.) relâchées à Marshall Bay (Ontario) contre l'euphorbe (*Euphorbia esula* L.). *Proceedings of the Entomological Society of Ontario* **127**: 125–126.

LeSage, L. 1996b. Expansion de l'aire de répatition de *Chrysolina hyperici* (Forster) depuis son introduction en Ontario (Coleoptera: Chrysomelidae). *Proceedings of the Entomological Society of Ontario* **127**: 127–130.

Li, S. Y. 2000. Larval susceptibility of balsam fir sawfly (Hymenoptera: Diprionidae) to neem. *Proceedings of the Entomological Society of Ontario* **110**: 139–143.

Loan, C. C. 1964. Observations on the biology of *Centistes excrucians* Haliday (Hymenoptera: Braconidae). *Proceedings of the Entomological Society of Ontario* **94**: 56–61.

Loan, C. C. 1965. Life cycle and development of *Leiophron pallipes* Curtis (Hymenoptera: Braconidae: Euphorinae) in five mired hosts in the Belleville district. *Proceedings of the Entomological Society of Ontario* **95**: 115–121.

Loan, C. C. 1970. Two new parasites of the tarnished plant bug in Ontario: *Leiophron pseudopallipes* and *Euphoriana lygivora* (Hymenoptera: Braconidae, Euphorinae). *Proceedings of the Entomological Society of Ontario* **100**: 188–195.

Loan, C. C. 1973. Parasitism of adult *Notoxus anchora* Henz. (Coleoptera: Anthicidae) by *Syrrhizus agilis* (Cresson) (Hymenoptera: Braconidae). *Proceedings of the Entomological Society of Ontario* **102**: 76.

Loan, C. 1982. Suppression of the fungi *Zoohthora* spp. by capitol: a technique to study interaction between disease and parasitism of the alfalfa weevil *Hyperica postica* (Coleoptera: Curculionidae). *Proceedings of the Entomological Society of Ontario* **112**: 81–82.

Loan, C. C. and New T. R. 1972. An account of the North American species of *Eurphoriella* Ashmead with descriptions of seven new species (Hymenoptera: Braconidae, Euphorinae). *Proceedings of the Entomological Society of Ontario* **102**: 92–108.

Lyons, D. B., Helson, B. V., Jones, G. C., McFarlane, J. W. and Scarr, T. 1996. Systemic activity of neem seed extracts containing azadirachtin in pine foliage for control of the pine false webworm, *Acantholyda erythrocephala* (Hymenoptera: Pamphiliidae). *Proceedings of the Entomological Society of Ontario* **127**: 45–55.

MacFarlane, R. P. and Pengelly, D. H. 1978. *Brachicoma* spp. (Sarcophagidae) and *Melittobia chalybii* (Eulophidae) as parasites of the brood of *Bombus* spp. (Apidae) in southern Ontario. *Proceedings of the Entomological Society of Ontario* **108**: 31–35.

Mackauer, M. 1971. 2. *Acyrthosiphon pisum* (Harris), pea aphid (Homoptera: Aphididae). Pp. 3–10 *in* McLeod, J. S., McGugan, B. M. and Coppel, H. C. (eds), *Biological control programmes against insects and weeds in Canada 1959–1968*. Technical Communication Commonwealth Institute of Biological Control 4, 266 pp.

Mackauer, M. J. P. and Bisdee, H. E. 1965. *Aphidius smithi* Sharma and Subba Rao (Hymenoptera: Aphidiidae) a parasitoid of the pea aphid new in southern Ontario. *Proceedings of the Entomological Society of Ontario* **95**: 121–124.

Mal, T. K., Loverr-Doust, J., Lovett-Doust. L. and Mulligan, G. A. 1992. The biology of Canadian weeds. 100. *Lythrum salicaria*. *Canadian Journal of Plant Science* **72**: 1305–1330.

Mason, P. G. and Huber, J. T. (eds) 2002. *Biological Control Programmes in Canada 1981–2000*. CABI Publishing, Wallingford, Oxon, United Kingdom, 583 pp.

Mason P. G. and Gillespie, D. R. (eds) 2013. *Biological Control Programmes in Canada 2001–2012*. CABI Publishing, Wallingford, Oxfordshire, United Kingdom, 518 pp.

Mason, P. G., Goulet, H. and Bostanian, N. 2011. Effect of harvest on Euphorine (Hymenoptera: Braconidae) parasitism of *Lygus lineolaris* and *Adelphocoris lineolatus* (Hemiptera: Miridae) in alfalfa. *Journal of the Entomological Society of Ontario* **142**: 3–10.

Maybee, G. E. 1954. Introduction into Canada of parasites of the carrot rust fly, *Psila rosae* (F.) (Diptera: Psilidae). *Annual Report of the Entomological Society of Ontario* **84**: 58–62.

Maybee, G. E. 1956. Observations, life-history, habits, immature stages, and rearing of *Loxotropa tritoma* (Thoms.) (Hymenoptera: Proctotrupoidea) a parasite of the carrot rust fly, *Psila rosae* (F.) (Diptera: Psilidae). *Annual Report of the Entomological Society of Ontario* **86**: 53–58.

Maxwell, C. W. and Morgan, G. T. 1952. Life-history studies of the cranberry fruitworm, *Mineola vaccinii* (Riley), in New Brunswick (Lepidoptera: Pyralidae). *Annual Report of the Entomological Society of Ontario* **83**: 21–25.

McClanahan, R. J., Boyce, H. R. and Code, W. R. 1968. The cereal leaf beetle - A new insect in Ontario. *Proceedings of the Entomological Society of Ontario* **98**: 21–26.

McLeod, J. H. 1962. Part I – Biological control of pests of crops, fruit trees, ornamentals, and weeds in Canada up to 1959. Pp. 1–34 *in* McLeod, J. S., McGugan, B. M. and Coppel, H. C. (eds), *A review of the biological control attempts against insects and weeds in Canada*. Technical Communication Commonwealth Institute of Biological Control 2, Franham Royal, Bucks, England, 216 pp.

McLeod, J. S., McGugan, B. M. and Coppel, H. C. (eds) 1962. *A review of the biological control attempts against insects and weeds in Canada*. Technical Communication Commonwealth Institute of Biological Control 2, Franham Royal, Bucks, England, 216pp.

McMullen, R. D. 1971. 16. *Psylla pyricola* Förster, pear psylla (Hemiptera: Psyllidae). Pp. 33–38 *in* Kelleher, J. S. et al. (eds), *Biological control programmes against insects and weeds in Canada 1959-1968*. Technical Communication Commonwealth Institute of Biological Control 4, Franham Royal, Slough, England, 266 pp.

Miller, L. A. and De Lyzer, A. J. 1960. A progress report on studies of biology and ecology of the six-spotted leafhopper, *Macrosteles fascifrons* (Stal), in southwestern Ontario. *Proceedings of the Entomological Society of Ontario* **90**: 7–13.

Monteith, L. G. 1976. Laboratory feeding studies of potential predators of the apple maggot *Rhagoletis pomonella* (Diptera: Tephritidae) in Ontario. *Proceedings of the Entomological Society of Ontario* **106**: 28–33.

Monteith, L. G. 1977. Field studies of potential predators of the apple maggot *Rhagoletis pomonella* (Diptera: Tephritidae) in Ontario. *Proceedings of the Entomological Society of Ontario* **107**: 23–30.

Monteith, L. G. 1978. Additional records and the role of the parasites of the apple maggot *Rhagoletis pomonella* (Diptera: Tephritidae) in Ontario. *Proceedings of the Entomological Society of Ontario* **108**: 3–6.

Moore, R. J. 1975. The biology of Canadian weeds. 13. *Cirsium arvense* (L.) Scop. *Canadian Journal of Plant Science* **55**: 1033–1048.

Morris, G. W. 1980. Microbial isolations from *Sitophilus zeamais* (Coleoptera: Curculionidae). *Proceedings of the Entomological Society of Ontario* **110**: 93–96.

Mulligan, G.A. and C. Frankton. 1954. The plumeless thistles (*Carduus* spp.) in Canada. *Canadian Field Naturalist* **68**: 31–36.

Murillo, H., Hunt, D. W. A. and Vanlaerhoven, S. L. 2012. Larval parasitoids of the cabbage looper, *Trichoplusi ni* (Lepidoptera: Noctuidae), in field tomato crops in southwestern Ontario. *Journal of the Entomological Society of Ontario* **143**: 115–119.

Nealis, V. G. and Bourchier, R. S. 1995. Reduced vulnerability to hyperparasitism in nondiapause strains of *Cotesia melanoscela* (Ratzeburg) (Hymenoptera: Braconidae) *Proceedings of the Entomological Society of Ontario* **126**: 29–35.

Nealis, V. G. and Quednau, F. W. 1996. Canadian field releases and overwinter survival of *Ceranthia samarensis* (Villeneuve) (Diptera: Tachinidae) for biological control of the gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae). *Proceedings of the Entomological Society of Ontario* **127**: 11–20.

Nystrom, K. L. and Evans, H. J. 1989. Biological notes on a birch leaf edgeminer, *Scolioneura betuleti* (Hymenoptera: Tenthredinidae), new to North America. *Proceedings of the Entomological Society of Ontario* **120**: 17–24.

Pengelly, D. H. 1961. *Thymelicus lineola* (Ochs.) (Lepidoptera: Hesperiidae) a pest of hay and pasture grasses in southern Ontario. *Proceedings of the Entomological Society of Ontario* **91**: 189–197.

Phillips, J. H. H. 1969. Parasitism of a population of the Oriental fruit moth, *Grapholitha molesta* Busck, in an unsprayed peach orchard. *Proceedings of the Entomological Society of Ontario* **99**: 81.

Philogene, B. J. R. and Chang, J. F. 1979. New records of parasitic chalcidoids of pear psylla (Homoptera: Psyllidae) in Ontario, with observations on the current world status of its parasitoids and predators. *Proceedings of the Entomological Society of Ontario* **109**: 53–63.

Poinar, G. O. Jr., Thomas, G. and Prokopy, R. J. 1978. Microorganisms associated with *Rhagoletis pomonella* (Diptera: Tephritidae) in Massachusetts. *Proceedings of the Entomological Society of Ontario* **108**: 19–22.

Pointing, P. J. and Green, G. W. 1962. A review of the history and biology of the European pine shoot moth, *Rhyacionia buoliana* (Schiff.) (Lepidoptera: Olethreutidae) in Ontario. *Proceedings of the Entomological Society of Ontario* **92**: 58–69.

Proverbs, M. D. 1962. Progress on the use of induced sexual sterility for the control of the codling moth *Carpocapsa pomonella* (L.) (Lepidoptera: Olethreutidae). *Proceedings of the Entomological Society of Ontario* **92**: 5–11.

Putnam, W. L. 1963. The codling moth, *Carpocapsa pomonella* (L.) (Lepidoptera: Tortricidae): A review with special reference to Ontario. *Proceedings of the Entomological Society of Ontario* **93**: 22–60.

Ragsdale, D. W., Voegtlin, D. J. and O'Neil, R. J. 2004. Soybean aphid biology in North America. *Annals of the Entomological Society of America* **97**: 204–208.

Ramey, C. A. 1990. Host identification and oviposition behaviour of a parasitic wasp, *Eurytoma obtusiventris* (Hymenoptera: Eurytomidae). *Proceedings of the Entomological Society of Ontario* **121**: 127.

Reid, D. G. and Harmsen, R. 1975. *Trirhabda borealis* Blake (Coleoptera: Chrysomelidae) a major phytophagous species on *Solidago canadensis* L. (Asteraceae) in south-eastern Ontario. *Proceedings of the Entomological Society of Ontario* **105**: 44–47.

Robinson, A. G. 1952. Annotated list of predators of tetranychid mites in Manitoba. *Annual Report of the Entomological Society of Ontario* **83**: 33–37.

Robinson, A. G. 1953. Notes on *Stethocorus punctum* (LEC.) (Coleoptera: Coccinellidae), a predator of tetranychid mites in Manitoba. *Annual Report of the Entomological Society of Ontario* **84**: 24–26.

Sharkey, M. 2007. Revision of the Neotropical genus *Trachagathis* Viereck (Hymenoptera: Braconidae: Agathidinae). *Journal of the Entomological Society of Ontario* **137**: 51–61.

Song, S. 1990. The effect of host encounter rate on fecundity of *Gelis tenellus* (Hymenoptera: Ichneumonidae). *Proceedings of the Entomological Society of Ontario* **121**: 129.

Stewart, J. G., Lund, J. E. and Thompson, L. S. 1992. Factors affecting the efficacy of *Bacillus thuringiensis* var San Diego against larvae of the Colorado potato beetle. *Proceedings of the Entomological Society of Ontario* **122**: 21–25.

Thistlewood, H. M. A., Bostanian, N. J. and Hardman, J. M. 2013. *Panonychus ulmi* (Koch) European red mite (Trombidiformes: Tetranychidae). Pp. 238–243 *in* Mason, P. G. and Gillespie, D. R. (eds), *Biological Control Programmes in Canada 2001–2012*. CABI Publishing, Wallingford, Oxfordshire, United Kingdom, 518 pp.

Tripp, H. A. 1972. Field trials to control spruce budworm, *Choristoneura fumiferana* (Clem.), through aerial application of *Bacillus thuringiensis*. *Proceedings of the Entomological Society of Ontario* **102**: 64–69.

Tyler, B. M. J. and Ellis, C. R. 1980. Ground beetles in three tillage plots in Ontario and observations on their importance as predators of the northern corn rootworm, *Diabrotica longicornis* (Coleoptera: Chrysomelidae). *Proceedings of the Entomological Society of Ontario* **110**: 65–73.

Vander Hoek, G. 1971. The larval instars of *Aphidius pulcher* Baker (Hymenoptera: Aphidiidae). *Proceedings of the Entomological Society of Ontario* **101**: 55–59.

Van Whervin, L. W. and Wilde, W. H. A. 1970. An analysis of the possibilities of the sterile male release technique in the eradication of the surgarcane moth borer, *Diatraea saccharalis* (F.), in Barbados West Indies. *Proceedings of the Entomological Society of Ontario* **100**: 111–113.

Villanueva, R. and Harmsen, R. 1996. Ecological interactions of tarsonemid mites in apple orchards: Predation of apple rust mite and use of *Phyllonorycter blancardella* mines. *Proceedings of the Entomological Society of Ontario* **127**: 99–106.

Vincent, C., Huber, J. T., Gibson, G. A. P. and Goulet, H. 2013. *Phyllonorycter blancardella* (Fabricius), spotted tentiform leafminer (Lepidoptera: Gracillariidae). Pp. 244–247 *in* Mason, P. G. and Gillespie, D. R. (eds), *Biological Control Programmes in Canada 2001–2012*. CABI Publishing, Wallingford, Oxfordshire, United Kingdom, 518 pp.

Wallace, D. R. and Sullivan, C. R. 1985. The white pine weevil, *Pissodes strobe* (Coleoptera: Curculionidae): a review emphasizing behavior and development in relation to physical factors. *Proceedings of the Entomological Society of Ontario* **116** Supplement: 39–62.

Wang, T. and Laing, J. E. 1989. Reproductive biology of *Holcothorax testaceipes* (Hymenoptera: Encyrtidae) and its effect on development of the host, *Phyllonorycter blancardella* (Lepidoptera: Gracillariidae). *Proceedings of the Entomological Society of Ontario* **120**: 35–41.

Wang, T. and Laing, J. E. 1990. Toxicity of selected insecticides to adult *Holcothorax testaceipes* (Hymenoptera: Encyrtidae), an imported parasitoid of *Phyllonorycter blancardella* (Lepidoptera: Gracillariidae). *Proceedings of the Entomological Society of Ontario* **121**: 119–122.

Welch, H. E. 1958. Test of a nematode and its associated bacterium for control of the Colorado potato beetle *Leptinotarsa decemlineata* (Say). *Annual Report of the Entomological Society of Ontario* **88**: 53–54.

Welch, H. E. 1962. Nematodes as agents for insect control. *Proceedings of the Entomological Society of Ontario* **92**: 11–19.

Welch, H. E. and Briand, L. J. 1961. Field experiment on the use of a nematode for the control of vegetable crop insects. *Proceedings of the Entomological Society of Ontario* **91**: 197–202.

West, A. S. and DeLong, B. 1956. Notes on the biology and laboratory rearing of a predatory insect, *Zelus exsanguis* (Stahl) (Hemiptera: Reduviidae). *Annual Report of the Entomological Society of Ontario* **86**: 97–101.

West, R. J. 1992. Notes on the biology and control of black army cutworm, *Actebia fennica* (Lepidoptera: Noctuidae), in black spruce plantations. *Proceedings of the Entomological Society of Ontario* **122**: 53–63.

West, R. J., Laing, J. E. and Marshall, S. A. 1984. Parasitoids of the potato stem borer, *Hydraecia micacea* (Lepidoptera: Noctuidae). *Proceedings of the Entomological Society of Ontario* **114**: 69–82.

Whistlecraft, J. W. and Lepard, I. J. M. 1989. Effect of flooding on survival of the onion fly *Delia antiqua* (Diptera: Anthomyiidae) and two parasitoids, *Aphaereta pallipes* (Hymenoptera: Braconidae) and *Aleochara bilineata* (Coleoptera: Staphylinidae). *Proceedings of the Entomological Society of Ontario* **120**: 43–47.

Whitfield, G. H., Drummond, F. A. and Haynes, D. L. 1981. A simulation model for the survival and development of the onion maggot *Hylemya antiqua* (Diptera: Anthomyiidae). *Proceedings of the Entomological Society of Ontario* **111**: 39–55.

Wilde W. H. A. 1965. The pear psylla, *Psylla pyricola* Foerster, in Ontario (Homoptera: Chermidae). *Proceedings of the Entomological Society of Ontario* **95**: 5–10.

Wilson, G. G. 1978. Observations on the incidence rates of *Nosema fumiferanae* (Microsporidia) in a spruce budworm, *Choristoneura fumiferana*, (Lepidoptera: Tortricidae) population. *Proceedings of the Entomological Society of Ontario* **108**: 144–145.

Wilson, G. G. 1980. Effects of *Nosema disstriae* (Microsporida) on the forest tent caterpillar, *Malacosoma disstria* (Lepidoptera: Lasiocampidae). *Proceedings of the Entomological Society of Ontario* **110**: 97–99.

Wilson, G. G. 1981. Effects of *Nosema fumiferanae* (Microsporida) on rearing stock of spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). *Proceedings of the Entomological Society of Ontario* **111**: 115–116.

Wilson, G. G. 1985a. The transmission and effects of *Nosema fumiferanae* and *Pleistophora schubergi* (Microsporida) on *Choristoneura fumiferana* (Lepidoptera: Tortricidae). *Proceedings of the Entomological Society of Ontario* **115**: 71–75.

Wilson, G.G. 1985b. Dose-mortality response of *Choristoneura fumiferana* (Lepidoptera: Tortricidae) to a microsporidium, *Pleistophora schubergi*. *Proceedings of the Entomological Society of Ontario* **115**: 93–94.

Wilson, G. G. 1987. The effects of *Vairimorpha necatris* (Microsporida) on the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). *Proceedings of the Entomological Society of Ontario* **117**: 91–93.

Wilson, G. G. and Burke, J. M. 1979. Microsporidian parasites of *Archips cerasivoranus* (Fitch) in the district of Algoma, Ontario. *Proceedings of the Entomological Society of Ontario* **109**: 84–85.

Woolhouse, M. E. J. and Harmsen, R. 1985. The mite complex on the foliage of a pesticide-free apple orchard: population dynamics and habitat associations. *Proceedings of the Entomological Society of Ontario* **115**: 1–11.

Wright, E. J. 1979. Observations on the copulatory behaviour of *Perilitus coccinellae* (Hymenoptera: Braconidae). *Proceedings of the Entomological Society of Ontario* **109**: 22.

Wright, E. J. and Laing, J. E. 1979. The effects of temperature on development, adult longevity and fecundity of *Coleomegilla maculate lengi* and its parasite *Perilitus coccinellae*. *Proceedings of the Entomological Society of Ontario* **109**: 33–47.

Wright, R. E. 1972. Nematode parasite of the face fly in Ontario. *Proceedings of the Entomological Society of Ontario* **102**: 168–175.

TABLE 1. Natural enemies introduced as classical biological control agents of invasive alien weeds in Ontario, 1952–2012.

Scientific name	Common name	Year first reported	Biological control agent	Year introduced	Reference
Carduus nutans L. (*Asteraceae*)	Nodding Thistle	1920[1]	*Rhinocyllus conicus* Froelich (Coleoptera: Cuculionidae)	1968	Laing & Heels (1979)
Cirsium arvense (L.) Scopoli (*Asteraceae*)	Canada Thistle	17th century[2]	*Urophora cardui* L. (Diptera: Tephritidae)	1975	Laing (1978)
Euphorbia esula L. (*Euphorbiaceae*)	Leafy Spurge	1889[3]	*Aphthona nigriscutis* Foudras (Coleoptera: Curculionidae)	1988	LeSage (1989)
			Aphthona flava Guillebeau (Coleoptera: Curculionidae)	1988	LeSage (1989)
Hypericum perforatum L. (*Hyperiaceae*)	St. John's Wort	1800s[4]	*Chrysolina hyperici* (Förster) (Coleoptera: Chrysomelidae)	1969	LeSage (1996b)
Lythrum salicaria L. (*Lythraceae*)	Purple Loosestrife	Early 19th century	*Neogalerucella calmariensis* (L.) [=*Galerucella calmariensis* L.] (Coleoptera: Curculionidae)	1992	Corrigan et al. (1998)

[1]Mulligan and Frankton (1954), [2]Moore (1975), [3]Best et al. (1980), [4]Crompton et al. (1988).

TABLE 2. Natural enemies introduced as classical biological control agents of invasive alien arthropods in Ontario, 1952–2012.

Scientific name	Common name	Year first reported	Biological control agent	Year introduced	Reference
Acyrtosiphon pisum (Harris) (Hemiptera: Aphididae)	Pea Aphid	1890s[1]	*Aphidius smithi* Sharma and Subba Rao (Hymenoptera: Aphidiidae)	1950s in USA	Mackauer & Bisdee (1965)
Agromyza frontella (Rondell) (Diptera: Agromyzidae)	Alfalfa Leaf Blotch Miner	Mid-1970s	*Dacnusa dryas* (Nixon) (Hymenoptera: Braconidae)	1979	Harcourt et al. (1987)
			Diglyphus isaea (Walker) (Hymenoptera: Eulophidae)	1975 (northeastern USA)	Coote & Ellis (1987)
			Cyrtogaster vulgaris Walker (Hymenoptera: Pteromalidae)	1976 (northeastern USA)	Coote & Ellis (1987)
Coleophora deauratella Lienig & Zeller (Lepidoptera: Coleophoridae)	Red Clover Case-bearer	1989	*Neochrysocharis formosa* (Westwood) (Hymenoptera: Eulophidae)	1993[2], 1995[2]	Ellis and Bjornson (1996)
Coleophora laricella (Hübner) (Lepidoptera: Coleophoridae)	Larch Casebearer	1935–1941	*Chrysocharis laricinellae* (Ratzeburg) (Hymenoptera: Eulophidae)	1935–1941	Graham (1958)
			Agathis pumilus (Ratzeburg) (Hymenoptera : Braconidae)	1935–1941	Graham (1958)
Cydia pomonella (L.) (Lepidoptera: Tortricidae)	Codling Moth	1958–1960	*Liotryphon caudatus* (Ratzeburg) [=*Apistephialtes caudata* (Ratzeburg)] (Hymenoptera: Ichneumonidae)	1941–1945	Putnam (1963)
			Nippocryptus vittatorius (Jurine) [=*Cryptus sexannulatus* Gravenhorst] (Hymenoptera: Ichneumonidae)	1941–1945	Putnam (1963)
			Elodia tragica (Meigen) (Diptera: Tachinidae)	1943–1944	Putnam (1963)
			Pristomerus vulnerator Panzer (Hymenoptera: Ichneumonidae)	1943–1944	Putnam (1963)
Hydraecia micacea (Esper) (Lepidoptera: Noctuidae)	Potato Stem Borer	1968	*Lydella stabulans* Fallén (Diptera : Tachnidae)	1983	West et al. (1984)

TABLE 2 continued...

Scientific name	Common name	Year first reported	Biological control agent	Year introduced	Reference
Hydraecia micacea (Esper) (Lepidoptera: Noctuidae)	Potato Stem Borer		*Macrocentrus blandus* Eady and Clark (Hymenoptera: Braconidae)	1983	West et al. (1984)
Hypera postica (Gyllenhal) (Coleoptera: Curculionidae)	Alfalfa Weevil	1960	*Bathyplectes anurus* (Thomson) (Hymenoptera: Ichneumonidae)	1970	Harcourt & Ellis (1992)
			Perilitus aethiops Nees [=*Microctonus aethiopoides* Loan] (Hymenoptera: Braconidae)	1970–1971	Harcourt et al. (1980)
			Perilitus colsei (Drea) [=*Microctonus colesi* Drea] (Hymenoptera: Braconidae)	1970	Harcourt et al. (1982)
			Zoophthora phytonomi (Arthur) Batko (Entomophthoraceae)		Harcourt & Ellis (1992)
Lymantria dispar (L.) (Lepidoptera: Erebidae)	Gypsy Moth	1969	*Cotesia melanoscela* (Ratzeburg) [=*Apanteles melanoscelus* (Ratzeburg)] (Hymenoptera: Braconidae)	Not introduced into Ontario	Griffiths (1977)
			Compsilura concinnata (Meigen) (Diptera: Tachinidae)	1916	Griffiths (1977)
			Parasetigena agilis (Robineau-Desvoidy) (Diptera: Tachinidae)	Not introduced into Ontario	Griffiths (1977)
			Ceranthia samarensis (Villeneuve) (Diptera: Tachinidae)	1991–1996	Nealis and Quednau (1996)
Oulema melanopus (L.) (Coleoptera: Chrysomelidae)	Cereal Leaf Beetle	1965	*Tetrastichus julis* (Walker) (Hymenoptera : Eulophidae)	1974	Ellis et al. (1979)
Pieris rapae (L.) (Lepidoptera: Pieridae)	Imported Cabbageworm	1871	*Cotesia rubecula* (Marshall) (Hymenoptera: Braconidae)	1991–1992	Carter & Laing (1997)
Psila rosae (Fabricius) (Diptera: Psilidae)	Carrot Rust Fly	1885	*Dacnusa gracilis* (Nees) (Hymenoptera: Braconidae)	1949–1953	Maybee (1954)
			Loxotropa tritoma (Thomson) (Hymenoptera: Proctotrupidae)	1949–1953	Maybee (1954)

TABLE 2 continued...

Scientific name	Common name	Year first reported	Biological control agent	Year introduced	Reference
Rhyacionia buoliana (Schiffermüller) (Lepidoptera: Tortricidae)	European Pine Shoot Moth	1925	*Campoplex difformis* (Gmelin) [=*Campoplex mutabilis* (Holmgren)] (Hymenoptera: Ichneumonidae)	1928–1953	Coppel & Arthur (1954)
			Sinophorus turionum (Ratzeburg) [=*Campoplex rufifemur* (Thomson)] (Hymenoptera: Ichneumonidae)	1928–1953	Coppel & Arthur (1954)
			Copidosoma filicorne (Dalman) [=*Copidosoma geniculatum* (Dalman)] (Hymenoptera: Eulophidae)	1928–1953	Coppel & Arthur (1954)
			Temeluca interruptor (Gravenhorst) [=*Cremastus interruptor* (Gravenhorst)] (Hymenoptera: Ichneumonidae)	1928–1953	Coppel & Arthur (1954)
			Exeristes ruficollis (Gravenhorst) [=*Ephialtes ruficollis* (Gravenhorst)] (Hymenoptera: Ichneumonidae)	1928–1953	Coppel & Arthur (1954)
			Orgilus obscurator (Nees) (Hymenoptera: Braconidae)	1928–1953	Coppel & Arthur (1954)
			Pimpla turionellae (L.) (Hymenoptera: Ichneumonidae)	1928–1953	Coppel & Arthur (1954)
			Pimpla sp. (Hymenoptera: Ichneumonidae)	1928–1953	Coppel & Arthur (1954)
			Baryscapus turionum (Hertig) [=*Tetrastichus turionum* (Hertig)] (Hymenoptera: Eulophidae)	1928–1953	Coppel & Arthur (1954)

[1] Mackauer, M. 1971. 2. *Acyrthosiphon pisum* (Harris), pea aphid (Homoptera: Aphididae). In: *Biological control programmes against insects and weeds in Canada 1959-1968*. Technical Communication Commonwealth Institute of Biological Control 4: 3–10.

[2]Some uncertainty whether populations released were *N. formosa* or *N. trifolii* (see text).

TABLE 3. Pathogens evaluated as inundative biological control agents of pest insects in Ontario, 1952–2012.

Scientific name	Common name	Biological control agent	Reference
Choristoneura fumiferana (Clemens) (Lepidoptera: Tortricidae)	Spruce Budworm	*Bacillus thuringiensis* Berliner (Bacilliaceae)	Tripp (1972)
		Entomopox virus (EPV) (*Baculoviridae*)	Bird et al. (1973)
		Nosema fumiferanae (Thompson) (Nosematidae)	Wilson (1978; 1981; 1985a)
		nuclear polyhedrosis virus (NPV) (*Baculoviridae*)	Bird et al. (1973)
		Pleistophora schubergi Zwölfer (Pleistophoridae)	Wilson (1985a, b)
		Vairimorpha necatrix (Kramer) (Nosematidae)	Wilson (1987)
Choristoneura pinus pinus (Freeman) (Lepidoptera: Tortricidae)	Jack Pine Budworm	*Bacillus thuringiensis* Berliner (Bacilliaceae)	Cadogan et al. (1987); Cadogan (1993)
Leptinotarsa decemlineata (Say) (Coleoptera: Chrysomelidae)	Colorado Potato Beetle	*Bacillus thuringiensis* Berliner serovar. *San Diego* (Bacilliaceae)	Stewart et al. (1992)
		Neaplectana chresima Steiner (Nematoda: Steinernematidae)	Welch (1958)
Lymantria dispar (L.) (Lepidoptera: Erebidae)	Gypsy Moth	*Bacillus thuringiensis* Berliner serovar. *kurstaki* (Bacilliaceae)	Cunningham et al. (1996a, b)
		nuclear polyhedrosis virus (NPV) (*Baculoviridae*)	Cunningham et al. (1996a, b)
Malacosoma disstria Hübner (Lepidoptera: Lasiocampidae)	Forest Tent Caterpillar	*Bacillus thuringiensis* Berliner (Bacilliaceae)	Angus (1965)
Neodiprion lecontei (Fitch) (Hymenoptera: Tenthredinidae)	Redheaded Pine Sawfly	*Lecontvirus* (*Baculoviridae*)	Cunningham et al. (1987)
Ostrinia nubilalis (Hübner) (Lepidoptera: Pyralidae)	European corn borer	*Autographa californica nuclear polyhedrosis virus* (ACNPV) (*Baculoviridae*)	Laing & Jaques (1985)
		Bacillus thuringiensis Berliner (Bacilliaceae)	Laing & Jaques (1985)
		Nosema pyrausta (Paillot) (Nosematidae)	Laing & Jaques (1985)
		Vairimorpha necatrix (Kramer) (Nosematidae)	Laing & Jaques (1985)
Pieris rapae (L.) (Lepidoptera: Pieridae)	Imported cabbageworm	*Pieris rapae GV* (*Baculoviridae*)	Jaques (1971)
Tricoplusia ni (Hübner) (Lepidoptera: Noctuidae)	Cabbage looper	*Tricoplusia ni GV* (*Baculoviridae*)	Jaques (1971)

APPENDIX A. Natural Enemies of insects and weeds reported in JESO (1952–2012). Correct name is first, followed by names as spelled in JESO in brackets, if they are different.

Host	Natural enemy	Order	Family	Feeding niche	Reference
Actebia fennica (Tauscher) (Lepidoptera: Noctuidae)	*Arenetra rufipes* Cresson	Hymenoptera	Ichneumonidae	parasitoid	West (1992)
	Campoletis sp.	Hymenoptera	Ichneumonidae	parasitoid	West (1992)
	Enicospilus sp.	Hymenoptera	Ichneumonidae	parasitoid	West (1992)
	Gonia sp.	Diptera	Tachinidae	parasitoid	West (1992)
	Ichneumon creperus Cresson	Hymenoptera	Ichneumonidae	parasitoid	West (1992)
	Steinernema feltiae (Filipjev)	Rhabiditida	Steinernematidae	parasite	West (1992)
	Tachinomyia panaetius (Walker)	Diptera	Tachinidae	parasitoid	West (1992)
Acrobasis sp. (Lepidoptera: Pyralidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Acrobasis vaccinii Riley [=*Mineola vaccinii* (Riley)] (Lepidoptera: Pyralidae)	*Phanerotoma franklini* Gahan	Hymenoptera	Braconidae	parasitoid	Maxwell & Morgan (1952)
	Cryptus albitarsis (Cresson)	Hymenoptera	Ichneumonidae	parasitoid	Maxwell & Morgan (1952)
Aculus schlechtendali (Nalepa) (Trombidiformes: Eriophyidae)	*Balaustium putnami* Smiley	Trombidiformes	Erythraeidae	predator	Cadogan & Laing (1982)
	Dendroptus n. sp. near *suskii* Sharonov and Livshitz [=*Dendroptus forestae* Lindquist)]	Trombidiformes	Tarsonemidae	predator	Villanueva & Harmsen (1996)
	Phytocoris sp.	Hemiptera	Miridae	predator	Hagley (1979)
	Zetzellia mali (Ewing)	Trombidiformes	Stigmaeidae	predator	Clements (1989)
Acyrthosiphon pisum (Harris) (Hemiptera: Aphididae)	*Aphelinus howardii* (Ashmead) [=*Aphelinus howardii* Dalla Torre]	Hymenoptera	Aphelinidae	parasitoid	Mackauer & Bisdee (1965)
	Aphelinus semiflavus Howard	Hymenoptera	Aphelinidae	parasitoid	Mackauer & Bisdee (1965)
	Aphidius colemani Viereck [=*Aphidius platensis* Brèthes]	Hymenoptera	Aphidiidae	parasitoid	Vander Hoek (1971)
	Aphidius ervi Haliday	Hymenoptera	Aphidiidae	parasitoid	Vander Hoek (1971)
	Aphidius nigripes Ashmead [=*Aphidius pulcher* Baker]	Hymenoptera	Aphidiidae	parasitoid	Mackauer & Bisdee (1965); Vander Hoek (1971)
	Aphidius smithi Sharma & Subba Rao	Hymenoptera	Aphidiidae	parasitoid	Mackauer & Bisdee (1965)
	Diaeretiella rapae (McIntosh) [=*Diaeretus rapae* (Curtis)]	Hymenoptera	Braconidae	parasitoid	Vander Hoek (1971)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Ephedrus californicus Baker	Hymenoptera	Aphidiidae	parasitoid	Mackauer & Bisdee (1965)
	Erynia neoaphidis Remaudière & Hennebert		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Monoctonus crepidis (Haliday) [=*Monoctonus paludum* Marshall]	Hymenoptera	Braconidae	parasitoid	Vander Hoek (1971)
	Monoctonus nervosus (Haliday) [=*Monoctonus paulensis* (Ashmead)]	Hymenoptera	Braconidae	parasitoid	Mackauer & Bisdee (1965)
	Praon pequodorum Viereck	Hymenoptera	Aphidiidae	parasitoid	Mackauer & Bisdee (1965)
	Praon sp.	Hymenoptera	Aphidiidae	parasitoid	Mackauer & Bisdee (1965)
Adelphocoris lineolatus (Goeze) (Hemiptera: Miridae)	*Leiophron dayi* (Goulet) [=*Peristenus dayi* Goulet	Hymenoptera	Braconidae	parasitoid	Mason et al. (2011)
	Leiophron mellipes (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
	Leiophron rubricollis (Thomson) [=*Peristenus rubricollis* (Thomson)]	Hymenoptera	Braconidae	parasitoid	Mason et al. (2011)
Adelphocoris rapidus Say (Hemiptera: Miridae)	*Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Aedes aegypti (L.) (Diptera: Culicidae)	*Neoaplectana* n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch (1962)
Agromyza frontella (Rondani) (Diptera: Agromyzidae)	*Asaphes vulgaris* Walker	Hymenoptera	Pteromalidae	parasitoid	Coote & Ellis (1987a)
	Baryscapus racemariae (Ashmead) [=*Tetrastichus centricolae* (Ashmead)]	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Chrysocharis giraulti Yoshimoto	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Chrysocharis liriomyzae Delucchi [=*Chrysocharis punctifacies* Delucchi]	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Closterocerus cinctipennis Ashmead	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Closterocerus trifasciatus Westwood [=*Closterocerus tricinctus* (Ashmead)]	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Cyrtogaster vulgaris Walker	Hymenoptera	Pteromalidae	parasitoid	Coote & Ellis (1987a)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Dacnusa dryas (Nixon)	Hymenoptera	Braconidae	parasitoid	Coote & Ellis (1987a); Harcourt et al. (1987)
	Diaulinopsis albiscapus (Girault)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Diaulinopsis callichroma Crawford	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Diglyphus begini (Ashmead)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Diglyphus intermedius (Girault)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Diglyphus isaea (Walker)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Diglyphus pulchripes (Crawford)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Eunotus sp.	Hymenoptera	Pteromalidae	parasitoid	Coote & Ellis (1987a)
	Hemiptarsenus ainsliei (Crawford) [=*Notanisomorpha ainsliei* Crawford]	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Miscogaster hortensis Walker	Hymenoptera	Pteromalidae	parasitoid	Coote & Ellis (1987a)
	Necremnus sp.	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Pnigalio maculipes (Crawford)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Pnigalio uroplatae (Howard)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Sympiesis ancylae Girault	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Sympiesis enargiae Miller	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Sympiesis sericeicornis (Nees) [=*Sympiesis conica* (Provancher)]	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Sympiesis sp.	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Sympiesis viridula (Thomson)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Tetrastichus n. sp.	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
	Tetrastichus cincinnatus (Girault) [=*Aprostocetus cincinnatus* (Girault)]	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987a)
Ancylis comptana (Frölich) [=*Ancylis comptana fragariae* (Walsh & Riley)] (Lepidoptera: Tortricidae)	*Macrocentrus ancylivora* Rohwer	Hymenoptera	Braconidae	parasitoid	Dustan & Boyce (1966)
Anisoplia austriaca (Herbst) (Coleoptera: Scarabaeidae)	*Metarrhizium anisopliae* (Metchnikoff) Sorokin		Clavicipitaceae	pathogen	Cameron (1969)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
aphids (Hemiptera: Aphididae)	*Adialytus salicaphis* (Fitch) [=*Diaeretus salicaphis* (Fitch)]	Hymenoptera	Braconidae	parasitoid	Judd (1953)
	Aphidius matricariae Haliday [=*Aphidius phorodontis* Ashmead]	Hymenoptera	Aphidiidae	parasitoid	Judd (1953)
	Asaphes suspensus (Nees) [=*Asaphes rufipes* Brues]	Hymenoptera	Pteromalidae	parasitoid	Judd (1953)
Aphidius phorodontis Ashmead (Hymenoptera: Braconidae)	*Lygocerus* sp.	Hymenoptera	Ceraphronidae	hyperparasitoid	Judd (1953)
	Alloxysta sp. [=*Charipes* sp.]	Hymenoptera	Aloxystidae	hyperparasitoid	Judd (1953)
Aphis glycines Matsumura (Hemiptera: Aphididae)	*Harmonia axyridis* (Pallas)	Coleoptera	Coccinellidae	predator	Bahlai et al. (2009)
Aphis pomi DeGeer (Hemiptera: Aphididae)	*Deraeocoris fasciolus* Knight	Hemiptera	Miridae	predator	Hagley (1979)
Aprophora saratogensis (Fitch) (Hemiptera: Cicadellidae)	*Ooctonus aphrophorae* Milliron	Hymenoptera	Mymaridae	parasitoid	Huber (2012)
Schizocerella pilicornis (Holmgren) [=*Aprosthena zabriskei* Webster & Malley] (Hymenoptera: Argidae)	*Anaphes conotracheli* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Archips cerasivorana (Fitch) (Lepidoptera: Tortricidae)	*Nosema scerasivoranus* Thomson		Nosematidae	pathogen	Wilson & Burke (1979)
	Pleistophora sp.		Pleistophoridae	pathogen	Wilson & Burke (1979)
	Thelohania sp.		Thelohaniidae	pathogen	Wilson & Burke (1979)
Archips purpuranus Clemens (Lepidoptera: Tortricidae)	*Macrocentrus nigridorsis* Viereck	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
	Microgaster canadensis Muesebeck [=*Microgaster canadensis* Muesbeck]	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
	Oncophanes americanus (Weed) [=*Oncophanes atriceps* (Ashmead) =*Oncophanes canadensis* (Muesbeck)]	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
Archips rosana (L.) (Lepidoptera: Tortricidae)	*Euema caesar* (Aldrich) [=*Zenilla caesar* Aldrich]	Diptera	Tachinidae	parasitoid	Hagley & Barber (1992)
	Microgaster canadensis Muesebeck	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
	Phorocera erecta Coquillett	Diptera	Tachinidae	parasitoid	Hagley & Barber (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Archips spp. (Lepidoptera: Tortricidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Argyrotaenia velutinana (Walker) (Lepidoptera: Tortricidae)	*Phytodietus vulgaris* Cresson [=*Phytodietus annulatus* (Provancher)]	Hymenoptera	Ichneumonidae	parasitoid	Hikichi (1962); Hagley & Barber (1992)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hikichi (1962); Hagley & Barber (1992)
Ascogaster quadridentata Wesmael (Hymenoptera: Braconidae)	*Dibrachys microgastri* (Bouché) [=*Dibrachys cavus* (Walker)]	Hymenoptera	Pteromalidae	hyperparasitoid	Putnam (1963)
	Perilampus fulvicornis Ashmead	Hymenoptera	Perilampidae	hyperparasitoid	Putnam (1963)
	Perilampus sp.	Hymenoptera	Perilampidae	hyperparasitoid	Putnam (1963)
	Perilampus tristis Mayr	Hymenoptera	Perilampidae	hyperparasitoid	Putnam (1963)
Autographa californica (Speyer) (Lepidoptera: Noctuidae)	*Cotesia yakutatensis* (Ashmead) [=*Apanteles yakutatensis* (Ashmead)]	Hymenoptera	Braconidae	parasitoid	West et al. (1984)
Bathyplectes curculionis (Thomson) (Hymenoptera: Ichneumonidae)	*Agrothereutes abbreviatus iridescens* (Cresson) [=*Agrothereutes abbreviator similaris* (Provancher)]	Hymenoptera	Ichneumonidae	hyperparasitoid	Abu & Ellis (1976)
	Agrothereutes sp.	Hymenoptera	Ichneumonidae	hyperparasitoid	Abu & Ellis (1976)
	Conura albifrons (Walsh) [=*Spilochalcis albifrons* (Walsh)]	Hymenoptera	Chalcididae	hyperparasitoid	Abu & Ellis (1976)
	Eupelmella vesicularis (Retzius)	Hymenoptera	Eupelmidae	hyperparasitoid	Abu & Ellis (1976)
	Eupelmus sp.	Hymenoptera	Eupelmidae	hyperparasitoid	Abu & Ellis (1976)
	Gelis sp.	Hymenoptera	Ichneumonidae	hyperparasitoid	Abu & Ellis (1976)
	Habrocytus sp.	Hymenoptera	Pteromalidae	hyperparasitoid	Abu & Ellis (1976)
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	hyperparasitoid	Abu & Ellis (1976)
	Pteromalus sp.	Hymenoptera	Pteromalidae	hyperparasitoid	Abu & Ellis (1976)
	Trichomalopsis viridescens (Walsh) [=*Eupteromalus viridescens* (Walsh)]	Hymenoptera	Pteromalidae	hyperparasitoid	Abu & Ellis (1976)
Bombus fervidus (Fabricius) (Hymenoptera: Apidae)	*Brachicoma devia* Fallen	Diptera	Sarcophagidae	parasitoid	MacFarlane & Pengelly (1978)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Melittobia chalybii Ashmead	Hymenoptera	Eulophidae	parasitoid	Edwards & Pengelly (1966); MacFarlane & Pengelly (1978)
Bombus impatiens Cresson (Hymenoptera: Apidae)	*Brachicoma setosa* Coquillett	Diptera	Sarcophagidae	parasitoid	MacFarlane & Pengelly (1978)
	Melittobia chalybii Ashmead	Hymenoptera	Eulophidae	parasitoid	MacFarlane & Pengelly (1978)
Bombus laboriosus (Fabricius) [=*Psithyrus laboriosus* (Fabricius)] (Hymenoptera: Apidae)	*Melittobia chalybii* Ashmead	Hymenoptera	Eulophidae	parasitoid	Edwards & Pengelly (1966)
Bombus perplexus Cresson (Hymenoptera: Apidae)	*Melittobia chalybii* Ashmead	Hymenoptera	Eulophidae	parasitoid	MacFarlane & Pengelly (1978)
Bombus vagans Smith (Hymenoptera: Apidae)	*Brachicoma sarcophagina* (Townsend)	Diptera	Sarcophagidae	parasitoid	MacFarlane & Pengelly (1978)
	Melittobia chalybii Ashmead	Hymenoptera	Eulophidae	parasitoid	MacFarlane & Pengelly (1978)
Bombyx mori (L.) (Lepidoptera: Bombycidae)	*Bacillus thuringiensis* Berliner serovar. *sotto* Aoki & Chigasaki		Bacillaceae	pathogen	Angus & Heimpel (1960)
Bruchophagus platyptera (Walker) [=*Bruchophagus platypterus* (Walker)] (Hymenoptera: Eurytomidae)	*Tetrastichus bruchophagi* Gahan	Hymenoptera	Pteromalidae	parasitoid	Ellis & Nang'ayo (1992)
	Mesopolobus bruchophagi (Gahan)	Hymenoptera	Pteromalidae	parasitoid	Ellis & Nang'ayo (1992)
Cacopsylla pyricola (Förster) [=*Psylla pyricola* Förster] (Hemiptera: Psyllidae)	*Adalia bipunctata* (L.)	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Adalia bipunctata frigida Schneider [=*Adalia frigida* Schneider]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Agulla sp.	Neuroptera	Rhaphidiidae	predator	Philogene & Chang (1979)
	Anthocoris antevolens White	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Anthocoris melanocerus Reuter	Hemiptera	Anthocoridae	predator	Wilde (1965); Philogene & Chang (1979)
	Anthocoris musculus Say	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Anthocoris nemoralis (Fabricius)	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Anthocoris nemorum L.	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Anthocoris pilosus (Jakovlev)	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Anthocoris sp.	Hemiptera	Anthocoridae	predator	Wilde (1965)
	Anthocoris whitei Reuter	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Asaphes vulgaris Walker	Hymenoptera	Pteromalidae	parasitoid/ hyperparasitoid	Philogene & Chang (1979
	Atractotomus mali Meyer	Neuroptera	Chrysopidae	predator	Philogene & Chang (1984
	Calvia quatuordecimguttata (L.) [=*Anisoclavia quatuordecimguttata* L. =*Calvia duodecimmaculata* Gebler]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Campylomma verbasci (Meyer-Dür)	Hemiptera	Miridae	predator	Philogene & Chang (1979)
	Ceratomegilla sp.	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979); Wilde (1965)
	Chrysopa carnea Stephens	Neuroptera	Chrysopidae	predator	Philogene & Chang (1985)
	Chrysopa oculata Say	Neuroptera	Chrysopidae	predator	Philogene & Chang (1986)
	Chrysopa ploribunda Fitch	Neuroptera	Chrysopidae	predator	Philogene & Chang (1987)
	Chrysopa sp.	Neuroptera	Chrysopidae	predator	Wilde (1965); Philogene & Chang (1979)
	Coccidencyrtus sp.	Hymenoptera	Pteromalidae	parasitoid	Philogene & Chang (1980; 1981)
	Coccinella transversoguttata richarsoni Brown [=*Coccinella transversoguttata* Falderman]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Coleomegilla maculata fuscilabris (Mulsant) [=*Magilla fuscilabris* Mulsant]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Cycloneda polita Casey	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Cycloneda sp.	Coleoptera	Coccinellidae	predator	Wilde (1965)
	Dendrocerus floridanus (Ashmead) [=*Lygocerus semiramosuns* Kieffer]	Hymenoptera	Ceraphronidae	parasitoid	Philogene & Chang (1979)
	Deraeocoris brevispiceatus Knight [=*Derseocoris brevispiceatus* Knight]	Hemiptera	Miridae	predator	Philogene & Chang (1979)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Deraeocoris fasciolus Knight [=*Derseocoris fasciolus* Knight]	Hemiptera	Miridae	predator	Philogene & Chang (1979)
	Diaphnocoris provancheri (Burque)	Hemiptera	Miridae	predator	Philogene & Chang (1979)
	Encyrtus sp.	Hymenoptera	Encyrtidae	parasitoid	Philogene & Chang (1979)
	Endopsylla agilis de Meijere	Diptera	Cecidomyiidae	parasitoid	Philogene & Chang (1979)
	Endopsylla sp.	Diptera	Cecidomyiidae	parasitoid	Philogene & Chang (1979)
	Hemerobius pacificus Banks	Neuroptera	Hemerobiidae	predator	Philogene & Chang (1979)
	Hemerobius angustus Banks	Neuroptera	Hemerobiidae	predator	Philogene & Chang (1979)
	Hemerobius sp.	Neuroptera	Hemerobiidae	predator	Philogene & Chang (1979)
	Hippodamia convergens Guérin-Méneville [=*Hyppodamia convergens* Guérin-Méneville]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Hippodamia quinquesignata (Kirby) [=*Hyppodamia quinquesignata* (Kirby)]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Hippodamia sp.	Coleoptera	Coccinellidae	predator	Wilde (1965)
	Hippodamia tredecimpunctata tibialis (Say) [=*Hyppodamia tredecimpunctata tibialis* (Say)]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Lasius pallitarsi (Provancher) [=*Lasius sitkaenisis* Pergande]	Hymenoptera	Formicidae	predator	Philogene & Chang (1979)
	Lygocerus sp.	Hymenoptera	Ceraphronidae	parasitoid	Philogene & Chang (1979)
	Olla v-nigrum (Mulsant) [=*Olla abdominalis* Say]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Orius sp.	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Orius tristicolor (White)	Hemiptera	Anthocoridae	predator	Philogene & Chang (1979)
	Pachyneuron californicum Girault	Hymenoptera	Pteromalidae	parasitoid/ hyperparasitoid	Philogene & Chang (1982)
	Pachyneuron sp.	Hymenoptera	Pteromalidae	parasitoid	Philogene & Chang (1983)
	Platypalpus sp.	Diptera	Hybotidae	predator	Philogene & Chang (1979)
	Prionomitus mitratus (Dalman)	Hymenoptera	Encyrtidae	parasitoid	Philogene & Chang (1979)
	Psyllaephagus sp.	Hymenoptera	Encyrtidae	parasitoid	Philogene & Chang (1979)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Scymnus marginicollis Mannerham [=*Scymnus marginiccelis* Mannerham]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Spaherosphoria sp.	Diptera	Syrphidae	predator	Philogene & Chang (1979)
	Stethorus punctum picipes Casey [=*Stethocrus picipes* Casey]	Coleoptera	Coccinellidae	predator	Philogene & Chang (1979)
	Trechnites insidiosus (Crawford) [=*Trechnites psyllae* (Ruschka)]	Hymenoptera	Encyrtidae	parasitoid	Wilde (1965); Philogene & Chang (1979)
Carduus acanthoides L. (*Asteraceae*)	*Rhinocyllus conicus* Frölich	Coleoptera	Curculionidae	phytophage	Laing & Heels (1979)
Carduus nutans L. (*Asteraceae*)	*Papaipema nebris* Guenée [=*Papaipema negris* Guenée]	Lepidoptera	Noctuidae	phytophage	Laing & Heels (1979)
	Platyptilia carduidactyla (Riley)	Lepidoptera	Pterophoridae	phytophage	Laing & Heels (1979)
	Rhinocyllus conicus Frölich	Coleoptera	Curculionidae	phytophage	Laing & Heels (1979)
Chaetocnema denticulata (Illiger) (Coleoptera: Chrysomelidae)	*Anaphes pullicrurus* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Chlamydatus sp. (Hemiptera: Miridae)	*Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Chlorochroa sayi Stål (Hemiptera: Pentatomidae)	*Telenomus utahensis* Ashmead	Hymenoptera	Scelionidae	parasitoid	Wang & Laing (1989)
Chlorochroa uhleri Stål (Hemiptera: Pentatomidae)	*Telenomus utahensis* Ashmead	Hymenoptera	Scelionidae	parasitoid	Wang & Laing (1989)
Choristoneura biennis Freeman (Lepidoptera: Tortricidae)	*entomopoxvirus EPV*		*Poxyviridae*	pathogen	Bird et al. (1973)
Choristoneura fumiferana (Clemens) (Lepidoptera: Tortricidae)	*Bacillus thuringiensis* Berliner		Bacillaceae	pathogen	Tripp (1973)
	entomopoxvirus EPV		*Poxyviridae*	pathogen	Bird et al. (1973)
	Nosema fumiferanae (Thomson)		Nosematidae	pathogen	Wilson (1978; 1985a; 1987)
	Nosema fumiferanae (Thomson)		Nosematidae	pathogen	Wilson (1981)
	Pleistophora schubergi Zwölfer		Pleistophoridae	pathogen	Wilson & Burke (1979); Wilson (1985a; b)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Pleistophora sp.		Pleistophoridae	pathogen	Wilson & Burke (1979)
	polyhedrosis virus NPV		*Baculoviridae*	pathogen	Bird et al. (1973)
	Thelohania sp.		Nosematidae	pathogen	Wilson (1987)
	Thelohania sp.		Thelohaniidae	pathogen	Wilson & Burke (1979)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Corrigan et al. (1994)
	Vairimorpha necatrix (Kramer)	Dissociodihaplo-phasida	Nosematidae	pathogen	Wilson (1987)
Choristoneura pinus pinus (Freeman) (Lepidoptera: Tortricidae)	*Bacillus thuringiensis* Berliner serovar. *kurstaki*		Bacillaceae	pathogen	Cadogan et al. (1987); Cadogan (1993)
Choristoneura rosaceana (Harris) (Lepidoptera: Tortricidae)	*Acropimpla alboricta* (Cresson)	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Actia interrupta Curran	Diptera	Tachinidae	parasitoid	Hagley & Barber (1992)
	Agrypon sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Apophua simplicipes (Cresson)	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Colpoclypeus florus (Walker)	Hymenoptera	Eulophidae	parasitoid	Hagley & Barber (1992)
	Elachertus sp.	Hymenoptera	Eulophidae	parasitoid	Hagley & Barber (1992)
	Glypta fumiferanae (Viereck)	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Glypta sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Macrocentrus linearis (Nees) [=*Macrocentrus irridescens* (French)]	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
	Nilea erecta (Coquillet)	Diptera	Tachinidae	parasitoid	Hagley & Barber (1992)
	Phytodietus sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Phytodietus vulgaris Cresson	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Pimpla aequalis Provancher	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Scambus versicarius Ratzeburg	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley & Barber (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Chrysops frigidus Osten-Sacken [=*Chrysops frigida* Osten-Sacken] (Diptera: Tabanidae)	*Diglochis occidentalis* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	James (1952)
Chrysops furcatus Walker [=*Chrysops furcata* Walker] (Diptera: Tabanidae)	*Diglochis occidentalis* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	James (1952)
Chrysops spp. (Diptera: Tabanidae)	*Diglochis occidentalis* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	James (1952)
	Prionocera dmidiata (Loew)	Diptera	Tipulidae	predator	James (1952)
Cirsium arvense (L.). Scopoli (*Asteraceae*)	*Urophora cardui* L.	Diptera	Tephritidae	phytophage	Laing (1978)
Cirsium vulgare (Savi) Tenore (*Asteraceae*)	*Rhinocyllus conicus* Frölich	Coleoptera	Curculionidae		Laing & Heels (1979)
Closterotomus norvegicus (Gmelin) [=*Calocoris norvegicus* Reuters] (Hemiptera: Miridae)	*Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Coleomegilla maculata lengi Timberlake (Coleoptera: Coccinellidae)	*Dinocampus coccinellae* (Schrank) [=*Perilitus coccinellae* (Shrank)]	Hymenoptera	Braconidae	parasitoid	Wright (1979); Wright & Laing (1979)
Coleophora alcyonipennella (Kollar) (Lepidoptera: Coleophoridae)	*Neochrysocharis formosus* (Westwood) [=*Neochrysocharis formosa* (Westwood)]	Hymenoptera	Eulophidae	parasitoid	Ellis & Bjørnson (1996)
Coleophora deauratella Lienig & Zeller (Lepidoptera: Coleophoridae)	*Bracon pygmaeus* Provancher	Hymenoptera	Braconidae	parasitoid	Ellis & Bjørnson (1996)
	Neochrysocharis formosus (Westwood) [=*Neochrysocharis formosa* (Westwood)]	Hymenoptera	Eulophidae	parasitoid	Ellis & Bjørnson (1996)
	Neochrysocharis trifolii Erdös [=*Chrysonotomyia trifolii* (Erdös)]	Hymenoptera	Eulophidae	parasitoid	Ellis & Bjørnson (1996)
Coleophora laricella (Hübner) (Lepidoptera: Coleophoridae)	*Agathis pumila* (Ratzeburg)	Hymenoptera	Braconidae	parasitoid	Graham (1958)
	Chrysocharis laricinellae (Ratzeburg)	Hymenoptera	Eulophidae	parasitoid	Graham (1958)
Coleophora mayrella (Hübner) (Lepidoptera: Coleophoridae)	*Neochrysocharis formosus* (Westwood) [=*Neochrysocharis formosa* (Westwood)]	Hymenoptera	Eulophidae	parasitoid	Ellis & Bjørnson (1996)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Coleophora pruniella (Clemens) (Lepidoptera: Coleophoridae)	*Orgilus scaber* Muesebeck [=*Orgilus scabriculus* Nees]	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
Coleophora tiliaefoliella Clemens (Lepidoptera: Coleophoridae)	*Gelis* sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Scambus decorus Walley	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Scambus sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
Conotrachelus geminatus LeConte (Coleoptera: Curculionidae)	*Anaphes conotracheli* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Conotrachelus nenuphar (Herbst) (Coleoptera: Curculionidae)	*Hippodamia tredecimpunctata tibialis* (Say)	Coleoptera	Coccinellidae	predator	Hagley (1979)
Cotesia melanoscela (Ratzeburg) [=*Apanteles melanoscelus* (Ratzeburg)] (Hymenoptera: Braconidae)	*Gelis tenellus* (Say)	Hymenoptera	Ichneumonidae	hyperparasitoid	Griffiths (1980); Song (1990)
Cotesia rubecula (Marshall) (Hymenoptera: Braconidae)	*Baryscapus galactopus* (Ratzeburg)	Hymenoptera	Eulophidae	hyperparasitoid	Carter & Laing (1997)
	Catolaccus sp.	Hymenoptera	Pteromalidae	hyperparasitoid	Carter & Laing (1997)
	Mesochorus vittator (Zetterstedt)	Hymenoptera	Ichneumonidae	hyperparasitoid	Carter & Laing (1997)
Craponius inaequalis (Say) (Coleoptera: Curculionidae)	*Anaphes conotracheli* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Culex annulirostris Skuse (Diptera: Culicidae)	*Paracleius germanus* Parent	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
Culex pipiens L. (Diptera: Culicidae)	*Dugesia tigrina* (Girard)	Tricladida	Duegesiidae	predator	George (1979; 1984)
Culex quinquefasciatus Say (Diptera: Culicidae)	*Paracleius germanus* Parent	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
Culex restuans Theobald (Diptera: Culicidae)	*Dolichopus gratus* Loew	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
	Dugesia tigrina (Girard)	Tricladida	Duegesiidae	predator	George (1979; 1984)
Cydia pomonella (L.) [=*Carpocapsa pomonella* (L.)] (Lepidoptera: Tortricidae)	*Agelena naevia* Walckenaer	Araneae	Agelenidae	predator	Putnam (1963)
	Anystis agilis Banks	Trombidiformes	Anystidae	predator	Putnam (1963)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Ascogaster quadridentata Wesmael [=*Ascogaster carpocapsae* (Viereck)]	Hymenoptera	Braconidae	parasitoid	Putnam (1963)
	Bacillus cereus Frankland & Frankland		Bacillaceae	pathogen	Angus & Heimpel (1960); Putnam (1963)
	Beauveria bassiana (Balsamo) Vuillemin		Moniliaceae	pathogen	Putnam (1963)
	Chrysopa carnea Stephens [=*Chrysops plorabunda* Fitch]	Neuroptera	Chrysopidae	predator	Putnam (1963)
	Chrysopa rufilabris Burmeister	Neuroptera	Chrysopidae	predator	Putnam (1963)
	Cryptus albitarsis (Cresson)	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Dendrocops pubescens (L.)	Piciformes	Picidae	predator	Putnam (1963)
	Dendrocops villosus (L.)	Piciformes	Picidae	predator	Putnam (1963)
	Dibrachys microgastri (Bouché) [=*Dibrachys cavus* (Walker) =*Dibrachys boucheanus* (Ratzeburg)]	Hymenoptera	Pteromalidae	parasitoid	Putnam (1963)
	Elodia tragica (Meigen)	Diptera	Tachindae	parasitoid	Putnam (1963)
	Eupelmus cyaniceps Ashmead	Hymenoptera	Eupelmidae	parasitoid	Putnam (1963)
	Eurytoma sp.	Hymenoptera	Eurytomidae	parasitoid	Putnam (1963)
	Glypta sp.	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Haplothrips faurei Hood	Thysanoptera	Phaelothripidae	predator	Putnam (1963)
	Hirsutella subulata Petch		Ophiocordycipitaceae	pathogen	Putnam (1963)
	Hoplocryptus sp.	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Hyaliodes vitripennis (Say)	Hemiptera	Miridae	predator	Putnam (1963)
	Hymenochaonia delicata (Cresson) [=*Macrocentrus delicatus* Cresson]	Hymenoptera	Braconidae	parasitoid	Putnam (1963)
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Leptothrips mali (Fitch)	Thysanoptera	Phaelothripidae	predator	Putnam (1963)
	Liotryphon caudatus (Ratzeburg) [=*Apistephialtes caudatus* (Ratzeburg)]	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Macrocentrus ancylivora Rohwer	Hymenoptera	Braconidae	parasitoid	Putnam (1963)
	Macrocentrus instabilis Muesebeck	Hymenoptera	Braconidae	parasitoid	Putnam (1963)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Mastrus carpocapsae (Cushman) [=*Aenoplex carpocapsae* Cushman]	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Mermis sp.	Mermithida	Mermithidae	parasite	Putnam (1963)
	Neoaplectana n. sp.	Rhabditida	Steinernematidae	parasite	Putnam (1963)
	Neoaplectana n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch (1962)
	Nippocryptus vittatorius (Jurine) [=*Cryptus sexannulatus* Gravenhorst]	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Nosema destructor Steinhaus & Hughes		Nosematidae	pathogen	Putnam (1963)
	Panonychus ulmi Koch	Trombidiformes	Tetranychidae	predator	Hagley (1979)
	Phanerotoma fasciata Provancher	Hymenoptera	Braconidae	parasitoid	Putnam (1963)
	Pimpla annulipes Brullé [=*Pimpla inflata* Townes]	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Plistophora californica Steinhaus & Hughes		Nosematidae	pathogen	Putnam (1963)
	Pristomerus vulnerator (Panzer)	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Scambus pterophori Ashmead [=*Pimpla pterela* Auctorum]	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Solenopsis molesta (Say)	Hymenoptera	Formicidae	predator	Putnam (1963)
	Temelucha minor (Cushman)	Hymenoptera	Ichneumonidae	parasitoid	Putnam (1963)
	Tenebroides corticalis Melsheimer	Coleoptera	Trogossitidae	predator	Putnam (1963)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley (1987); Hagley & Laing (1989)
	Trichogramma minutum Riley [=*Trichogramma emryophagum* Hertig]	Hymenoptera	Trichogrammatidae	parasitoid	Putnam (1963)
	Trichogramma pretiosum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley (1987); Hagley & Laing (1989)
	Trichogramma sp.	Hymenoptera	Trichogrammatidae	parasitoid	Putnam (1963)
Cylindrocopturus adspersus (LeConte) (Coleoptera: Curculionidae)	*Anaphes pallipes* (Ashmead)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Cylindrocopturus furnissi Buchanan (Coleoptera: Curculionidae)	*Dinotiscus dendroctoni* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
Dasyneura albovittata Walsh (Diptera: Cecidomyiidae)	*Ceraphron* sp.	Hymenoptera	Ceraphronidae	parasitoid	Judd (1953)
	Leptacis sp.	Hymenoptera	Platygasteridae	parasitoid	Judd (1953)
	Tetrastichus sp.	Hymenoptera	Eulophidae	parasitoid	Judd (1953)
	Torymus sp.	Hymenoptera	Torymidae	parasitoid	Judd (1953)
Delia antiqua (Meigen) [=*Hylemya antiqua* Meigen] (Diptera: Anthomyiidae)	*Aleochara bilineata* Gyllenhal	Coleoptera	Staphylinidae	parasitoid	Whistlecraft & Lepard (1989)
	Aphaereta pallipes (Say)	Hymenoptera	Braconidae	parasitoid	Whitfield et al. (1981); Whistlecraft & Lepard (1989)
	Entomophthora muscae (Cohn) Fresen		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
Delia radicum (L.) [=*Hylemya brassicae* L.] (Diptera: Anthomyiidae)	*Heterotylenchus* sp.	Nematoda	Sphaerulariidae	parasite	Wright (1972)
	Neoaplectana n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch & Briand (1961); Welch (1962)
Delia spp. [=*Hylemya* spp.] (Diptera: Anthomyiidae)	*Phygadeuon trichops* Thomson	Hymenoptera	Ichneumonidae	parasitoid	Maybee (1956)
Dendroctonus frontalis Zimmermann (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
Dendroctonus spp. (Coleoptera: Curculionidae)	*Dinotiscus dendroctoni* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
Diabrotica barberi R.F. Smith & Lawrence [=*Diabrotica longicornis* (Say)] (Coleoptera: Chrysomelidae)	*Agonum muelleri* (Herbst)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Amara avida Say	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Amara sp.	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Anisodactylus rusticus (Say)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Anisodactylus sanctaecrucis (Fabricius)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Bembidion quadrimaculatum oppositum Say	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Bembidion tetracolum Say	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Bembidion versicolor (LeConte)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Blemus discus (Fabricius) [=*Lasiotrechus discus* Fabricius]	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Carabus nemoralis Müller	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Clivina fossor (L.)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Colliuris pensylvanica L.	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Dyschirius sp.	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Harpalus affinis (Schrank)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Harpalus pensylvanicus (DeGeer)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Harpalus pleuriticus Kirby	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Notiophilus aquaticus (L.)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Patrobus longicornis (Say)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Poecilus lucublandus (Say) [=*Pterostichus lucublandus* Say]	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Pterostichus melanarius (Illiger)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Stenolophus comma (Fabricius)	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Tachys sp.	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
	Trechus apicalis Motschulsky	Coleoptera	Carabidae	predator	Tyler & Ellis (1980)
Diabrotica trivitta (Mannerheim) (Coleoptera: Chrysomelidae)	*Howardula beninga* Cobb	Tylenchida	Allantonematidae	parasite	Briand (1960)
Dibolia borealis Chevrolat (Coleoptera: Chrysomelidae)	*Anaphes behmani* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Diprion hercyniae (Hartig) (Hymenoptera: Diprionidae)	*polyhedrosis virus NPV*		*Baculoviridae*	pathogen	Bird et al. (1973)
Drosophila melanogaster Meigen (Diptera: Drosophilidae)	*Basalys tritomus* Thomson [=*Loxotropa tritoma* (Thomson)]	Hymenoptera	Diapriidae	parasitoid	Maybee (1956)
	Zelus exsanguis (Stål)	Orthoptera	Mantidae	predator	West & DeLong (1956)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Drosophila subobscura Collin (Diptera: Drosophilidae)	*Parasitylenchus diplogenus* Welch	Tylenchida	Allantonematidae	parasite	Welch (1962)
Elasmopalpus lingosellus (Zeller) (Lepidoptera: Pyralidae)	*Trachagathis rubricincta* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Sharkey (2007)
Empoasca fabae Harris (Hemiptera: Cicadellidae)	*Anagrus armatus* (Ashmead)	Hymenoptera	Mymaridae	parasitoid	Appleton et al. (2004)
	Zoophthora radicans (Brefeld) Batko [=*Erynia radicans* (Brefeld) Humber, Ben-Ze'ev & Kenneth]		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Zoophthora radicans (Brefeld) Batko [=*Erynia radicans* (Brefeld)]		Entomophthoraceae	pathogen	Appleton et al. (2004)
Ephestia kuehniella Zeller [=*Anagasta kuhniella* (Zeller)] (Lepidoptera: Pyralidae)	*Bacillus thuringiensis* Berliner serovar. *thuringiensis*		Bacillaceae	pathogen	Angus & Heimpel (1960)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley & Laing (1989); Corrigan & Laing (1992); Corrigan et al. (1994)
	Trichogramma pretiosum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley & Laing (1989)
Epiblema scudderiana (Clemens) (Lepidoptera: Tortricidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
	Bassus binominatus (Muesebeck) [=*Agathis binominata* Muesebeck]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
	Macrocentrus pallisteri DeGant	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
	Perilampus fulvicornis Ashmead	Hymenoptera	Perilampidae	hyperparasitoid	Laing & Heraty (1982)
	Scambus pterophori Asmead	Hymenoptera	Ichneumonidae	parasitoid	Laing & Heraty (1982)
Epiblema strenuana (Walker) (Lepidoptera: Tortricidae)	*Glypta rufiscutellaris* Cresson	Hymenoptera	Ichneumonidae	parasitoid	Boyce & Dustan (1954)
Epinotia sp. (Lepidoptera: Tortricidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Eriosoma lanigerum (Hausmann) (Hemiptera: Aphididae)	*Aphelinus mali* Haldeman	Hymenoptera	Aphelinidae	parasitoid	Hagley & Laing (1989)
Euphorbia esula L. (*Euphorbiaceae*)	*Aphthona czwalinae* Weise	Coleoptera	Chrysomelidae	phytophage	LeSage (1996a)
	Aphthona flava Guillebeau	Coleoptera	Chrysomelidae	phytophage	LeSage (1996a)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Aphthona nigriscutis Foudras	Coleoptera	Chrysomelidae	phytophage	LeSage (1996a)
Eurosta solidaginis (Fitch) (Diptera: Tephritidae)	*Eurytoma obtusiventris* Gahan	Hymenoptera	Eurytomidae	parasitoid	Ramey (1990)
Exartema sp. (Lepidoptera: Tortricidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Exeristes comstockii (Cresson) (Diptera: Tachinidae)	*Trichomalopsis viridescens* (Walsh)	Hymenoptera	Pteromalidae	parasitoid	Murillo et al. (2012)
Frankliniella occidentalis (Pergande) (Thysanoptera: Thripidae)	*Neoseiulus cucumeris* (Oudemans) [=*Amblyseius cucumeris* (Oudemans)	Mesostigmata	Phytoseiidae	predator	Jones et al. (2006)
Gerris sp. (Hemiptera: Gerridae)	*Anaphes gerrisophaga* (Doutt)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Gnorimoschema gallaesolidaginis (Riley) (Lepidoptera: Gelechiidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Gorytes costalis Cresson [=*Psammecius costalis* (Cresson)] (Hymenoptera: Crabronidae)	*Elampus viridicyaneus* Norton	Hymenoptera	Chrysididae	parasitoid	Huber & Pengelly (1977)
Grapholita molesta (Busck) [=*Grapholitha molesta* (Busck)] (Lepidoptera: Tortricidae)	*Enytus obliteratus* (Cresson) [=*Diadegma obliteratum* (Cresson)]	Hymenoptera	Ichneumonidae	parasitoid	Boyce & Dunstan (1954); Dunstan & Boyce 1966)
	Glypta rufiscutellaris Cresson	Hymenoptera	Ichneumonidae	parasitoid	Boyce & Dustan (1954); Dustan & Boyce (1966)
	Hymenochaonia delicata (Cresson) [=*Macrocentrus delicatus* Cresson]	Hymenoptera	Braconidae	parasitoid	Boyce & Dunstan (1954); Dunstan & Boyce 1966)
	Macrocentrus ancylivora Rohwer	Hymenoptera	Braconidae	parasitoid	Boyce & Dustan (1954); Dustan & Boyce (1966); Philips (1969)
	Temelucha minor (Cushman) [=*Cremastus minor* Cushman]	Hymenoptera	Ichneumonidae	parasitoid	Boyce & Dustan (1954); Dustan & Boyce (1966)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley (1987)
grasshoppers (Orthoptera: Acrididae)	*Pseudomonas aeruginosa* (Schroeter) Migula		Bacillaceae	pathogen	Angus & Heimpel (1960)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Hedya chionosema (Zeller) (Lepidoptera: Tortricidae)	*Macrocentrus nigridorsis* Viereck	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
Hedya nubiferana (Haworth) (Lepidoptera: Tortricidae)	*Cotesia acauda* (Provancher) [=*Cotesia acaudus* Provancher]	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)
Heliothis spp. (Lepidoptera: Noctuidae)	*Trichogramma pretiosum* Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley & Laing (1989)
Helioverpa virescens (Fabricius) [=*Heliothis virescens* (Fabricius)] (Lepidoptera: Noctuidae)	*Neoaplectana* n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch (1962)
Hyalopsocus striatus (Walker) (Psocoptera: Psocidae)	*Leiophron* (*Euphoriella*) *criddlei* (Loan & New) [=*Euphoriella criddlei* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron foutsi (Loan & New) [=*Euphoriella foutsi* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron hyalopsocidis (Loan & New) [=*Euphoriella hyalopsocidis* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron incerta (Ashmead) [=*Euphoriella incerta* Ashmead]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron kaladarensis (Loan & New) [=*Euphoriella kaladarensis* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron nixoni (Loan & New) [=*Euphoriella nixoni* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron pacifica (Muesebeck) [=*Euphoriella pacifica* Muesebeck]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron pallidifacia (Loan & New) [=*Euphoriella pallidifacia* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron solidaginis (Loan & New) [=*Euphoriella solidaginis* Loan & New]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
	Leiophron sommermanae (Muesebeck) [=*Euphoriella sommermanae* Muesebeck]	Hymenoptera	Braconidae	parasitoid	Loan & New (1972)
Hydraecia micacea (Esper) (Lepidoptera: Noctuidae)	*Campoletis* sp.	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)
	Centrodora near *locustrum* Girault	Hymenoptera	Aphelinidae	parasitoid	West et al. (1984)
	Diadegma sp.	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Epirus sp.	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)
	Exephanes occupator Gravenhorst	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)
	Glypta sp.	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)
	Lydella radicis (Townsend)	Diptera	Tachinidae	parasitoid	West et al. (1984)
	Lydella stabulans (Meigen)	Diptera	Tachinidae	parasitoid	West et al. (1984)
	Macrocentrus blandus Eady & Clark	Hymenoptera	Braconidae	parasitoid	West et al. (1984)
	Macrocentrus infirmus (Nees)	Hymenoptera	Braconidae	parasitoid	West et al. (1984)
	Pterocormus sp.	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)
	Telenomus sp.	Hymenoptera	Scelionidae	parasitoid	West et al. (1984)
	Therion sp.	Hymenoptera	Ichneumonidae	parasitoid	West et al. (1984)
	Trichogramma retorridum (Girault)	Hymenoptera	Trichogrammatidae	parasitoid	West et al. (1984)
Hypera brunneipennis (Boheman) (Coleoptera: Curculionidae)	*Anaphes luna* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypera compta (Say) (Coleoptera: Curculionidae)	*Anaphes nigrellus* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Hypera crinitus (Boheman) [=*Donus crinitus* Boehman] (Coleoptera: Curculionidae)	*Anaphes luna* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypera eximia (LeConte) (Coleoptera: Curculionidae)	*Anaphes luna* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
	Anaphes nigrellus Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Hypera nigrirostris (Fabricius) (Coleoptera: Curculionidae)	*Anaphes conotracheli* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypera paludicola Warner (Coleoptera: Curculionidae)	*Anaphes nigrellus* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Hypera postica (Gyllenahl) (Coleoptera: Curculionidae)	*Anaphes fuscipennis* Haliday	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes luna (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
	Anaphes nigrellus Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Bathyplectes anurus (Thomson)	Hymenoptera	Ichneumonidae	parasitoid	Harcourt & Ellis (1992)
	Bathyplectes curculionis (Thomson)	Hymenoptera	Ichneumonidae	parasitoid	Abu & Ellis (1976); Harcourt & Ellis (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Beauveria bassiana (Balsamo) Vuillemin		Moniliaceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Entomophthora (*Tarichium*) *punctata* Garbowski		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Entomophthora phytonomi Arthur		Entomophthoraceae	pathogen	Harcourt et al. (1980)
	Erynia phytonomi (Arthur) Humber, Ben-Ze'ev & Kenneth		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Erynia sp.		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Perilitus aethiops Nees [=*Microctonus aethiopoides* Loan	Hymenoptera	Braconidae	parasitoid	Harcourt et al. (1980; 1982); Loan (1982)
	Perilitus colesi (Drea) [=*Microctonus colesi* Drea	Hymenoptera	Braconidae	parasitoid	Harcourt et al. (1982); Loan (1982)
	Tarichium phytonomi Jaczewski		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Zoophthora phytonomi (Arthur) Batko		Entomophthoraceae	pathogen	Harcourt & Ellis (1992)
	Zoophthora spp.		Entomophthoraceae	pathogen	Loan (1982)
Hypera punctata (Fabricius) (Coleoptera: Curculionidae)	*Anaphes fuscipennis* Haliday	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes luna (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypera trilineata Marsham (Coleoptera: Curculionidae)	*Anaphes luna* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypera variabilis Herbst (Coleoptera: Curculionidae)	*Anaphes luna* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypera zoilus Scopoli (Coleoptera: Curculionidae)	*Anaphes luna* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Hypericum perforatum L. (*Hyperiaceae*)	*Chrysolina hyperici* (Förster)	Coleoptera	Chrysomelidae	phytophage	LeSage (1996b)
Hyraecia petasitis Doubleday (Lepidoptera: Noctuidae)	*Macrocentrus blandus* Eady & Clark	Hymenoptera	Braconidae	parasitoid	West et al. (1984)
Ips calligraphis (Germar) (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
Ips grandicollis (Eichhoff) (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
Ips pini (Say) (Coleoptera: Curculionidae)	*Rhopalicus tutela* (Walker)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Ips spp. (Coleoptera: Curculionidae)	*Dinotiscus dendroctoni* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
Labops hirtus Knight (Hemiptera: Miridae)	*Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Lasius neoniger Emery (Hymeoptera: Formicidae)	*Pseudometagea schwarzii* (Ashmead)	Hymenoptera	Eucharitidae	parasitoid	Heraty (1985)
Lasius sp. (Hymenoptera: Formicidae)	*Pseudometagea schwarzii* (Ashmead)	Hymenoptera	Eucharitidae	parasitoid	Heraty (1985)
Lebia vittata (Fabricius) [=*Diabrotica vittata* (Fabricius)] (Coleoptera: Chrysomelidae)	*Howardula beninga* Cobb	Tylenchida	Allantonematidae	parasite	Briand (1960)
Lema cyanella (L.) (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Lema lichenis Voet (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Lema trilineata (Olivier) (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Huber (1993)
Lema trivittata trivittata (Say) [=*Lema trilineata trivittata* (Say)] (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Huber (1994)
Leptinotarsa decemlineata (Say) (Coleoptera: Chrysomelidae)	*Bacillus thuringiensis* Berliner		Bacillaceae	pathogen	Stewart et al. (1992)
	Horismenus puttleri (Grissell) [=*Edovum puttleri* Grissell]	Hymenoptera	Eulophidae	parasitoid	Corrigan et al. (1990)
	Neoaplectana chresima Steiner	Rhabditida	Steinernematidae	parasite	Welch (1958)
	Neoaplectana n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch & Briand (1961); Welch (1962)
Leptopterna dolobrata (L.) (Hemiptera: Miridae)	*Leiophron mellipes* (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Lestes sp. (Odonata: Lestidae)	*Anaphes gerrisophaga* (Doutt)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Lioligus nitidus (Motschulsky) (Coleoptera: Byrridae)	*Anaphes byrrhidiphagus* Huber	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Lioon simplicipes (Mannerheim) (Coleoptera: Byrridae)	*Anaphes byrrhidiphagus* Huber	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Liriomyza sativae Blanchard (Diptera: Agromyzidae)	*Diglyphus intermedius* (Girault)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987b)
Liriomyza trifoliearum Spencer [=*Liriomyza trifolearum* Spencer] (Diptera: Agromyzidae)	*Diglyphus intermedius* (Girault)	Hymenoptera	Eulophidae	parasitoid	Coote & Ellis (1987b)
Listronotus oregonensis (LeConte) (Coleoptera: Curculionidae)	*Anaphes conotracheli* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Lygus hesperus Knight (Hemiptera: Miridae)	*Geocoris pallens* Stâhl	Hemiptera	Geocoridae	predator	Mason et al. (2011)
	Geogoris punctipes (Say)	Hemiptera	Geocoridae	predator	Mason et al. (2011)
	Nabis alternatus Parshley	Hemiptera	Nabidae	predator	Mason et al. (2011)
	Nabis americoferus (Carayon)	Hemiptera	Nabidae	predator	Mason et al. (2011)
	Orius tristicolor (White)	Hemiptera	Anthocoridae	predator	Mason et al. (2011)
Lygus lineolaris (Palisot) [=*Liocoris lineolaris* (Beauvois)]	*Leiophron pseudopallipes* (Loan) [=*Peristenus pseudopallipes* Loan	Hymenoptera	Braconidae	parasitoid	Broadbent et al. (1999); Mason et al. (2011)
	Leiophron dayi (Goulet) [=*Peristenus dayi* Goulet]	Hymenoptera	Braconidae	parasitoid	Mason et al. (2011)
	Leiophron digoneutis (Loan) [=*Peristenus digoneutis* Loan]	Hymenoptera	Braconidae	parasitoid	Broadbent et al. (1999); Mason et al. (2011)
	Leiophron lygivora (Loan)	Hymenoptera	Braconidae	parasitoid	Broadbent et al. (1999); Mason et al. (2011)
	Leiophron mellipes (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965); Broadbent et al. (1999); Mason et al. (2011)
	Leiophron rubricollis (Thomson) [=*Peristenus rubricollis* (Thomson) =*Peristenus conradi* Marsh]	Hymenoptera	Braconidae	parasitoid	Broadbent et al. (1999); Mason et al. (2011)
	Leiophron uniformis (Gahan)	Hymenoptera	Braconidae	parasitoid	Broadbent et al. (1999)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Lygus spp. (Hemiptera: Miridae)	*Anaphes iole* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Leiophron mellipes (Cresson) [=*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Lymantria dispar (L.) [=*Porthetria dispar* L.] (Lepidoptera: Erebidae)	*Bacillus thuringiensis* Berliner serovar. *kurstaki*		Bacillaceae	pathogen	Cunningham et al. (1996a; b)
	Ceranthia samarensis (Villeneuve)	Diptera	Tachinidae	parasitoid	Nealis & Quendau (1996)
	Compsilura concinnata (Meigen)	Diptera	Tachinidae	parasitoid	Griffiths (1977)
	Cotesia melanoscela (Ratzeburg)	Hymenoptera	Braconidae	parasitoid	Nealis & Bourchier (1995)
	Cotesia melanoscela (Ratzeburg) [=*Apanteles melanoscelus* (Ratzeburg)]	Hymenoptera	Braconidae	parasitoid	Griffiths (1976)
	Ooencyrtus kuvanae (Howard)	Hymenoptera	Encyrtidae	parasitoid	Hagley & Laing (1989)
	Parasetigena agilis (Robineau-Desvoidy)	Diptera	Tachinidae	parasitoid	Griffiths (1978)
	Pimpla pedalis Cresson	Hymenoptera	Ichneumonidae	parasitoid	Griffiths (1979)
	Pleistophora schubergi Zwölfer		Pleistophoridae	pathogen	Wilson (1985a)
Lythrum salicaria L. (*Lythraceae*)	*Neogalerucella calmariensis* (L.) [=*Galerucella calmariensis* (L.)]	Coleoptera	Chrysomelidae	phytophage	Corrigan et al. (1998)
Macrocentrus spp. (Hymenoptera: Braconidae)	*Eupelmus cyaniceps* Ashmead	Hymenoptera	Eupelmidae	hyperparasitoid	Putnam (1963)
Macrosteles fascifrons (Stål) (Hemiptera: Cicadellidae)	*Epigonatopus plesius* Fenton	Hymenoptera	Dryinidae	parasitoid	Miller & De Lyzer (1960)
Malacosoma disstria Hübner (Lepidoptera: Lasiocampidae)	*Aleiodes malacosomatos* (Mason) [=*Rogas malacosomatos* Mason]	Hymenoptera	Braconidae	parasitoid	Harmsen & Rose (1984)
	Bacillus thuringiensis Berliner		Bacillaceae	pathogen	Angus (1965)
	Nosema disstriae Thompson		Nosematidae	pathogen	Wilson (1980)
	Phobocampe clisiocampae (Weed)	Hymenoptera	Ichneumonidae	parasitiod	Harmsen & Rose (1984)
	Vairimorpha necatrix (Kramer)	Dissociodihaplo-phasida	Nosematidae	pathogen	Wilson (1987)
	Zelus exsanguis (Ståhl)	Orthoptera	Mantidae	predator	West & DeLong (1956)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Marmara fraxinicola Braun (Lepidoptera: Gracilariidae)	*Ageniaspis bicoloripes* (Girault) [=*Paraleurocerus bicoloripes* Girault]	Hymenoptera	Encyrtidae	parasitoid	Wang & Laing (1989)
Melolontha spp. (Coleoptera: Scarabaeidae)	nematode	Nematoda		parasite	Welch (1962)
Meteorus hyphantriae Riley [=*Meteorus hyphantria* Riley] (Hymenoptera: Ichneumonidae)	*Gelis* sp.	Hymenoptera	Ichneumonidae	hyperparasitoid	Pengelly (1961)
Morellia hortorum (Fallén) (Diptera: Muscidae)	*Heterotylenchus* sp.	Nematoda	Sphaerulariidae	parasite	Wright (1972)
Musca autumnalis DeGeer (Diptera: Muscidae)	*Heterotylenchus autumnalis* Nickle	Nematoda	Sphaerulariidae	parasite	Gregory & Wright (1973); Wright (1972)
	Entomophthora sp.		Entomophthoraceae	pathogen	Gregory & Wright (1973)
Musca vetutissima Walker (Diptera: Muscidae)	*Heterotylenchus* sp.	Nematoda	Sphaerulariidae	parasite	Wright (1972)
Mythima unipuncta (Haworth) [=*Pseudaletia unipuncta* (Haworth)] (Lepidoptera: Noctuidae)	*Apanteles* sp.	Hymenoptera	Braconidae	parasitoid	Goble (1965)
	Betabaculovirus sp. [=*Borrelinavirus* sp.]		*Baculoviridae*	disease	Goble (1965)
	Winthemia sp.	Diptera	Tachinidae	parasitoid	Goble (1965)
Myzus persicae (Sulzer) (Hemiptera: Aphididae)	*Entomophthora planchoniana* Cornu		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
Nabis capsiformis Germar [=*Reduviolus capsiformis* (Germar); *Reduviolus blackburni* (Kirkaldy)] (Hemiptera: Nabidae)	*Stephanodes reduvioli* (Perkins)	Hymenoptera	Mymaridae	parasitoid	Huber & Fildago (1997)
Neodiprion lecontei (Fitch) (Hymenoptera: Diprionidae)	*Lecontvirus* (*redheaded pine sawfly NPV*)		*Baculoviridae*	pathogen	Cunnigham et al. (1987)
Neodiprion pratti banksianae Rohwer [=*Neodiprion banksiana*] (Hymenoptera: Diprionidae)	*polyhedrosis virus*		*Baculoviridae*	pathogen	Cameron (1969)
Neodiprion sertifer (Geoffroy) (Hymenoptera: Diprionidae)	*Pleolophus basizonus* (Gravenhorst)	Hymenoptera	Ichneumonidae	parasitoid	Griffiths (1972)
	polyhedrosis virus		*Baculoviridae*	pathogen	Cameron (1969)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	polyhedrosis virus NPV		*Baculoviridae*	pathogen	Bird et al. (1973)
Notoxus anchora Hentz (Coleoptera: Anthicidae)	*Centistes agilis* (Cresson) [=*Syrrhizus agilis* (Cresson)]	Hymenoptera	Braconidae	parasitoid	Loan (1973)
Nycteola cinereana Neumoegen & Dyar [= *Sarrothripus cinereana* Neumoegen & Dyar] (Lepidoptera: Nolidae)	*Bacillus thuringiensis* Berliner		Bacillaceae	pathogen	Angus (1965)
Nymphalis antiopa (L.) (Lepidoptera: Nymphalidae)	*Bacillus thuringiensis* Berliner		Bacillaceae	pathogen	Angus (1965)
Orocrambus simplex Butler [=*Crambus simplex* Butler] (Lepidoptera: Crambidae)	*Neoaplectana leucaniae* Hoy	Rhabditida	Steinernematidae	parasite	Welch (1962)
Oryctes rhinoceros (L.) (Coleoptera: Scarabaeidae)	*Neoaplectana glaseri* Steiner	Rhabditida	Steinernematidae	parasite	Welch (1962)
Oscinella frit (L.) (Diptera: Chloropidae)	*Basalys tritomus* (Thomson) [=*Loxotropa tritoma* (Thomson)]	Hymenoptera	Diapriidae	parasitoid	Maybee (1956)
Ostrinia nubilalis (Hübner) (Lepidoptera: Crambidae)	*Autographa californica NPV* (ACNPV)		*Baculoviridae*	pathogen	Laing & Jacques (1985)
	Bacillus thuringiensis Berliner		Bacillaceae	pathogen	Laing & Jacques (1985)
	Neoaplectana n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch & Briand (1961); Welch (1962)
	Nosema heliothidis Lutz & Splendor		Nosematidae	pathogen	Wilson (1985a)
	Nosema pyrausta (Paillot)		Nosematidae	pathogen	Laing & Jacques (1985)
	Vairimorpha necatrix (Kramer)		Nosematidae	pathogen	Laing & Jacques (1985)
Oulema collaris (Say) (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Oulema gallaeciana (Heydon) (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Oulema melanopus (L.) (Coleoptera: Chrysomelidae)	*Anaphes flavipes* (Förster)	Hymenoptera	Mymaridae	parasitoid	Ellis et al. (1989); Huber (1992)
	Tetrastichus julis (Walker)	Hymenoptera	Eulophidae	parasitoid	Ellis et al. (1979; 1989)
Pandemis sp. (Lepidoptera: Tortricidae)	*Triclistus* sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Panonychus ulmi (Koch) [=*Metatetranychus ulmi* (Koch)] (Trombidiformes: Tetranychidae)	*Adalia bipunctata* (L.)	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Amblyseius spp.	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Balaustium putnami Smiley	Trombidiformes	Erythraeidae	predator	Cadogan & Laing (1982)
	Balaustium sp.	Trombidiformes	Erythraeidae	predator	Woolhouse & Harmsen (1985)
	Neoseiulus cucumeris (Oudemans) [=*Typhlodromus cucumeris* Oudemans]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Neoseiulus fallacis (Garman) [=*Typhlodromus fallacis* (Garman)]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Phytoseius macropilis (Banks)	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus bakeri (Garman) [=*Typhlodromus (Neoseiulus) bakeri* (Garman)]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus caudiglans (Schuster)	Mesostigmata	Phytoseiidae	predator	Clements (1989)
	Typhlodromus conspicuus (Garman)	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus conspicuus var. *herbertae* Nesbitt	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus finlandicus (Oudemans) [=*Typhlodromus finlandicus* Oudemans]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus longipilus Nesbitt	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus masseei (Nesbitt) [=*Typhlodromus masseei* Nesbitt]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus pomi (Parrott, Hodgkiss & Shoene) [=*Typhlodromus pomi* (Parrott) Garman]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus rhenanus (Oudemans) [=*Typhlodromus (Neoseiulus) rhenanus* Oudemans]	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus tiliae Oudemans	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Typhlodromus tiliarum (Garman)	Mesostigmata	Phytoseiidae	predator	Herbert (1953)
	Zetzellia mali (Ewing)	Trombidiformes	Stigmaeidae	predator	Clements (1989)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Periplaneta americana (L.) (Orthoptera: Blattidae)	*Melittobia chalybii* Ashmead	Hymenoptera	Eulophidae	parasitoid	Edwards & Pengelly (1966)
Philaenus spumarius (L.) (Hemiptera: Cercropidae)	*Erynia petchii* (Ben-Ze'ev & Kenneth)		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Ooctonus vulgatus Haliday	Hymenoptera	Mymaridae	parasitoid	Huber (2012)
Phthorimaea operculella (Zeller) (Lepidoptera: Gelechiidae)	*Chelonus kellieae* Marsh	Hymenoptera	Braconidae	parasitoid	Wang & Laing (1989)
	Chelonus phthorimaeae Gahan	Hymenoptera	Braconidae	parasitoid	Wang & Laing (1989)
Phyllonorycter blancardella (Fabricius) [=*Lithocolletis blancardella* Fabricius] (Lepidoptera: Gracillaridae)	*Achrysocharoides* sp. [=*Enaysma* sp.]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Ageniaspis testaceipes (Ratzeburg) [=*Holcothorax testaceipes* (Ratzeburg)]	Hymenoptera	Encyrtidae	parasitoid	Wang & Laing (1989)
	Baryscapus nigroviolaceus (Nees) [=*Tetrastichus amethystinus* (Ratzeburg)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Chrysocharis nepereus (Walker) [=*Chrysocharis cuspidogaster* Yoshimoto]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Chrysocharis pubens Delucchi	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Cirrospilus elegantissimus Westwood	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Cirrospilus lyncus Walker [=*Atoposomoidea lyncus* Walker]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Cirrospilus lyncus Walker [=*Atoposomoidea unifasciata* (Förster)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Closterocerus sp.	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Copidosoma truncatellum (Dalman)	Hymenoptera	Encyrtidae	parasitoid	Wang & Laing (1989)
	Minotetrastichus frontalis (Nees) [=*Tetrastichus cyclogaster* (Ratzeburg)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Minotetrastichus frontalis (Nees) [=*Tetrastichus xanthops* (Ratzeburg)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Minotetrastichus platanellus (Mercet) [=*Tetrastichus platanellus* (Mercet)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Neochrysocharis formosus (Westwood) [=*Achrysocharella formosa* (Westwood)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Pediobius saulius (Walker)	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Pholetesor circumscriptus (Nees) [=*Apanteles blancardellae* Bouché]	Hymenoptera	Braconidae	parasitoid	Johnson et al. (1977)
	Pholetesor circumscriptus (Nees) [=*Apanteles flavolimbatus* Ratz]	Hymenoptera	Braconidae	parasitoid	Johnson et al. (1977)
	Pholetesor circumscriptus (Nees) [=*Apanteles lautellus* Marsh]	Hymenoptera	Braconidae	parasitoid	Johnson et al. (1977)
	Pholetesor circumscriptus Nees [=*Apanteles circumscriptus* Nees]	Hymenoptera	Braconidae	parasitoid	Johnson et al. (1977)
	Pholetesor ornigis (Weed)	Hymenoptera	Braconidae	parasitoid	Fisher (1988)
	Pholetesor ornigis (Weed) [=*Apanteles ornigis* Weed]	Hymenoptera	Braconidae	parasitoid	Johnson et al. (1977)
	Pholetesor pedias (Nixon)	Hymenoptera	Braconidae	parasitoid	Fisher (1988)
	Pholetesor pedias (Nixon) [=*Apanteles bicolor* Nees]	Hymenoptera	Braconidae	parasitoid	Johnson et al. (1977)
	Pnigalio minio (Walker) [=*Pnigalio flavipes* (Ashmead)]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Pnigalio uroplatae (Howard)	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Sympiesis dolicogaster Ashmead	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Sympiesis gordius (Walker) [=*Sympiesis marylandensis* Girault]	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Sympiesis gordius Walker	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
	Sympiesis sericeicornis (Nees)	Hymenoptera	Eulophidae	parasitoid	Johnson et al. (1977)
Phyllonorycter ringoniella Matsumura (Lepidoptera: Gracillaridae)	*Ageniaspis testaceipes* (Ratzeburg) [=*Holcothorax testaceipes* (Ratzeburg)]	Hymenoptera	Encyrtidae	parasitoid	Wang & Laing (1989; 1990)
Phyllophaga spp. (Coleoptera: Scarabaeidae)	*Pelecinus polyturator* (Drury)	Hymenoptera	Pelecinidae	parasitoid	Bennett (2004)
Pieris rapae (L.) (Lepidoptera: Pieridae)	*Bacillus thuringiensis* Berliner		Bacillaceae	pathogen	Jaques (1971)
	Compsilura concinnata (Meigen)	Diptera	Tachindae	parasitoid	Harcourt (1963)
	Cotesia glomerata (L.) [=*Apanteles glomeratus* (L.)]	Hymenoptera	Braconidae	parasitoid	Harcourt (1963); West et al. (1984); Wang & Laing (1989)
	Cotesia rubecula (Marsh) [= *Apanteles rubecula* Marsh]	Hymenoptera	Braconidae	parasitoid	Wang & Laing (1989)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Cotesia rubecula (Marshall)	Hymenoptera	Braconidae	parasitoid	Corrigan (1983); Carter & Laing (1997)
	Helicobia rapax (Walker) [*Helocobia rapax* Walker]	Diptera	Sarcophagidae	parasitoid	Harcourt (1963)
	Madremyia saundersii (Williston)	Diptera	Tachindae	parasitoid	Harcourt (1963)
	Neoaplectana n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch & Briand (1961); Welch (1962)
	Phryxe vulgaris (Fallén)	Diptera	Tachindae	parasitoid	Harcourt (1963)
	Pieris rapae GV [=*P. rapae GV*] (PrGV)		*Baculoviridae*	pathogen	Jaques (1971)
	Pteromalus puparum (L.)	Hymenoptera	Pteromalidae	parasitoid	Harcourt (1963)
	Tetrastichus sp.	Hymenoptera	Eulophidae	parasitoid	Corrigan (1983)
Pimpla annulipes Brullé (Hymenoptera: Ichneumonidae)	*Eupelmus cyaniceps* Ashmead	Hymenoptera	Eupelmidae	hyperparasitoid	Putnam (1963)
Pissodes approximatus Hopkins (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
Pissodes nemorensis Germar (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
Pissodes strobi (Peck) (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
	Dolichomitus terebrans nubilipennis (Viereck) [=*Dolichotomitus terebrans nubilipennis* (Viereck)]	Hymenoptera	Ichneumonidae	parasitoid	Wallace & Sullivan (1985)
	Eurytoma pissodis Girault	Hymenoptera	Eurytomidae	parasitoid	Wallace & Sullivan (1985)
	Lonchaea corticis Taylor	Diptera	Lonchaeidae	predator	Wallace & Sullivan (1985)
	Ooctonus quadricarinatus Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2012)
	Rhopalicus tutela (Walker)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
Plagiognathus brunneus (Provancher) [=*Plagiognathus medicagus* Arrand] (Hemiptera: Miridae)	*Leiophron mellipes* (Cresson) [*Peristenus mellipes* (Cresson); not *Peristenus pallipes* (Curtis) =*Leiophron pallipes* Curtis]	Hymenoptera	Braconidae	parasitoid	Loan (1965)
Plodia interpunctella (Hübner) (Lepidoptera: Pyralidae)	*Nosema plodiae* Kellen & Lindgren		Nosematidae	pathogen	Wilson (1985a)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Plutella xylostella (L.) [=*Plutella maculipennis* (Curtis)] (Lepidoptera: Plutellidae)	*Campoletis* sp.	Hymenoptera	Ichneumonidae	parasitoid	Harcourt (1963)
	Conura albifrons (Walsh) [=*Spilochalcis albifrons* (Walsh)]	Hymenoptera	Chalcididae	parasitoid	Harcourt (1963)
	Diadegma insulare (Cresson)	Hymenoptera	Ichneumonidae	parasitoid	Bolter & Laing (1984)
	Diadegma insulare (Cresson) [=*Horogenes insularis* (Cresson)]	Hymenoptera	Ichneumonidae	parasitoid	Harcourt (1963)
	Diadromus subtilicornis (Gravenhorst)	Hymenoptera	Ichneumonidae	parasitoid	Bolter & Laing (1984)
	Diadromus subtilicornis (Gravenhorst) [=*Diadromus plutellae* (Ashmead)]	Hymenoptera	Ichneumonidae	parasitoid	Harcourt (1963)
	Dibracys microgastri (Bouché) [=*Dibrachys cavus* (Walker)]	Hymenoptera	Pteromalidae	parasitoid	Harcourt (1963)
	Gelis tenellus (Say)	Hymenoptera	Ichneumonidae	parasitoid	Harcourt (1963)
	Microplitis plutellae Muesbeck	Hymenoptera	Braconidae	parasitoid	Harcourt (1963); Bolter & Laing (1984)
	Oomyzus sokolowskii (Kurdjumov) [=*Tetrastichus sokolowskii* Kurdjumov]	Hymenoptera	Eulophidae	parasitoid	Harcourt (1963)
	Pteromalus sp. near *phycidis* Ashmead [=*Habrocytus* sp. near *phycidis* Ashmead]	Hymenoptera	Pteromalidae	parasitoid	Harcourt (1963)
Polygraphus spp. (Coleoptera: Curculionidae)	*Dinotiscus dendroctoni* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
Popillia japonica Newman (Coleoptera: Scarabaeidae)	*Bacillus lentimorbus* Dutky		Bacillaceae	pathogen	Angus & Heimpel (1960)
	Bacillus popilliae Dutky		Bacillaceae	pathogen	Angus & Heimpel (1960)
	Neoaplectana glaseri Steiner	Rhabditida	Steinernematidae	parasite	Welch (1962)
Pristiphora erichsonii (Hartig) (Hymenoptera: Tenthredinidae)	*Bacillus cereus* Frankland & Frankland		Bacillaceae	pathogen	Angus & Heimpel (1960)
Pseudaletia unipuncta (Haworth) (Lepidoptera: Noctuidae)	*Vairimorpha necatrix* (Kramer)	Dissociodihaplophasida	Nosematidae	pathogen	Wilson (1987)
Pseudatomoscelis sp. (Hemiptera: Miridae)	*Anaphes iole* Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Pseudexentera mali Freeman (Lepidoptera: Tortricidae)	*Diadegma* sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
Pseudosciaphila sp. [=*Sciaphila* sp.] (Lepidoptera: Olethreutidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Psila rosae (Fabricius) (Diptera: Psilidae)	*Aleochara sparsa* Heer	Coleoptera	Staphylinidae	parasitoid	Maybee (1954)
	Basalys tritomus Thomson [=*Loxotropa tritoma* (Thomson)]	Hymenoptera	Diapriidae	parasitoid	Maybee (1954; 1956)
	Chorebus posticus (Haliday) [=*Dacnusa gracilis* (Nees)]	Hymenoptera	Braconidae	parasitoid	Maybee (1954; 1956)
	Kleidotoma sp.	Hymenoptera	Eucoilidae	parasitoid	Maybee (1954)
Rhabdophaga strobiloides Walsh (Diptera: Cecidomyiidae)	*Copidosoma* sp.	Hymenoptera	Encyrtidae	parasitoid	Judd (1953)
	Torymus cecidomyae (Walker) [=*Torymus strobiloides* (Huber)]	Hymenoptera	Torymidae	parasitoid	Judd (1953)
	Tridymus sp.	Hymenoptera	Pteromalidae	parasitoid	Judd (1953)
Rhagoletis pomonella (Walsh) (Diptera: Tephritidae)	*Xenorhabdus nematophilus* (Poinar & Thomas) [=*Achromobacter nematophilus* Poinar & Thomas]		Enterobacteriaceae	pathogen	Poinar et al. (1977)
	Allonemobius fasciatus (DeGeer)	Orthoptera	Gryllidae	predator	Monteith (1976)
	Amblyseius fallacis Garman	Mesostigmata	Phytoseiidae	predator	Hagley (1979)
	Anaphes conotracheli Girault	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
	Anaphes pallipes (Ashmead)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
	Bacillus cereus Frankland & Frankland		Bacillaceae	pathogen	Poinar et al. (1977)
	Calosoma calidum (Fabricius)	Coleoptera	Carabidae	predator	Monteith (1976; 1977)
	Diachasma alloeum (Muesebeck) [=*Opius alloeus* Muesebeck]	Hymenoptera	Braconidae	parasitoid	Monteith (1978)
	Diachasma ferrugineum (Gahan) [=*Opius ferrugineus* Gahan]	Hymenoptera	Braconidae	parasitoid	Monteith (1978)
	Diachasmimorpha mellea (Gahan) [=*Opius melleus* Gahan]	Hymenoptera	Braconidae	parasitoid	Monteith (1978)
	Enterobacter sp.		Enterobacteriaceae	pathogen	Poinar et al. (1977)
	Escherichia coli (Migula) Castellani and Chalmers		Enterobacteriaceae	pathogen	Poinar et al. (1977)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Forficula auricularia L.	Dermaptera	Forficulidae	predator	Monteith (1976; 1977)
	Geotrichium sp.		Endomycetaceae	pathogen	Poinar et al. (1977)
	Gryllus pennsylvanicus Burmeister	Orthoptera	Gryllidae	predator	Monteith (1976)
	Harpalus pensylvanicus (DeGeer)	Coleoptera	Carabidae	predator	Monteith (1976; 1977)
	Lithobius forficatus (L.)	Lithobiomorpha	Lithobiidae	predator	Monteith (1976; 1977)
	Neoaplectana sp.	Rhabditida	Steinernematidae	parasite	Poinar et al. (1977)
	Oniscus laevis (Koch)	Isopoda	Oniscidae	predator	Monteith (1976)
	Oxidus rathkei (Koch)	Polydesmida	Paradoxosomatidae	predator	Monteith (1976)
	Porcellio laevis Latreille [=*Oniscus laevis* (Koch)]	Isopoda	Oniscidae	predator	Monteith (1977)
	Pseudomonas aeruginosa (Schroeter) Migula		Bacillaceae	pathogen	Poinar et al. (1977)
	Staphylinus badipes (LeConte)	Coleoptera	Staphylinidae	predator	Monteith (1976; 1977)
	Streptococcus sp.		Streptococcaceae	pathogen	Poinar et al. (1977)
	Trachelipus rathkii (Koch) [=*Oxidus rathkei* (Koch)]	Polydesmida	Paradoxosomatidae	predator	Monteith (1977)
	Utetes canaliculatus (Gahan) [=*Opius lectus* Gahan]	Hymenoptera	Braconidae	parasitoid	Monteith (1978)
	Utetes lectoides (Gahan) [=*Opius lectoides* Gahan]	Hymenoptera	Braconidae	parasitoid	Monteith (1978)
Rhopalosiphum maidis (Fitch) (Hemiptera: Aphididae)	*Adalia bipunctata* (L.)	Coleoptera	Coccinellidae	predator	Foott (1974)
	Coccinella novemnotata Herbst	Coleoptera	Coccinellidae	predator	Foott (1974)
	Coccinella transversoguttata Faldermann	Coleoptera	Coccinellidae	predator	Foott (1974)
	Coccinella trifasciata perplexa Mulsant	Coleoptera	Coccinellidae	predator	Foott (1974)
	Coleomegilla maculata lengi Timberlake	Coleoptera	Coccinellidae	predator	Foott (1974)
	Cycloneda sanguinea (L.)	Coleoptera	Coccinellidae	predator	Foott (1974)
	Hippodamia convergens Guérin-Méneville	Coleoptera	Coccinellidae	predator	Foott (1974)
	Hippodamia parenthesis (Say)	Coleoptera	Coccinellidae	predator	Foott (1974)
	Hippodamia tridecempunctata tibialis (Say)	Coleoptera	Coccinellidae	predator	Foott (1974)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Rhopalosiphum padi (L.) (Hemiptera: Aphididae)	*Entomophthora planchoniana* Cornu		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
Rhyacionia buoliana Denis & Schiffermüller (Lepidoptera: Tortricidae)	*Bacillus thuringiensis* Berliner		Bacillaceae	parasitoid	Pointing & Green (1962)
	Baryscapus turionum (Hartig) [=*Tetrastichus turionum* (Hartig)]	Hymenoptera	Eulophidae	parasitoid	Coppel & Arthur (1954); Pointing & Green (1962)
	Campoplex difformis (Gmelin) [=*Campoplex mutabilis* (Holmgren)]	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Campoplex sp.	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Copidosoma filicorne (Dalman) [=*Copidosoma geniculatum* (Dalmen)]	Hymenoptera	Encyrtidae	parasitoid	Coppel & Arthur (1954)
	Eurytoma appendigaster (Swederus)	Hymenoptera	Eurytomidae	parasitoid	Coppel & Arthur (1954)
	Exeristes comstockii (Cresson) [=*Calliephialtes comstockii* (Cresson)]	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Exeristes ruficollis (Gravenhorst) [=*Ephialtes ruficollis* (Gravenhorst)]	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Habrocytus sp.	Hymenoptera	Pteromalidae	parasitoid	Coppel & Arthur (1954)
	Hyssopus thymus Girault	Hymenoptera	Eulophidae	parasitoid	Coppel & Arthur (1954)
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Itoplectis sp.	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Orgilus obscurator (Nees)	Hymenoptera	Braconidae	parasitoid	Coppel & Arthur (1954); Pointing & Green (1962)
	Pimpla sp.	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Pimpla turionellae (L.)	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954); Pointing & Green (1962)
	Scambus hispae (Harris)	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Sinophorus turionum (Ratzeburg) [=*Campoplex rufifemur* (Thomson)]	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954)
	Temelucha interruptor (Gravenhorst) [=*Cremastus interruptor* (Gravenhorst)]	Hymenoptera	Ichneumonidae	parasitoid	Coppel & Arthur (1954); Pointing & Green (1962
Saperda candida Fabricius (Coleoptera: Cerambycidae)	*Melittobia chalybii* Ashmead	Hymenoptera	Eulophidae	parasitoid	Edwards & Pengelly (1966)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Schistocerca spp. (Orthoptera: Acrididae)	*Coccobacillus acridiorum* d'Herelle		Bacillaceae	pathogen	Angus & Heimpel (1960)
Scolioneura betuleti (Klug) (Hymenoptera: Tenthredinidae)	*Chrysocharis laricinellae* (Ratzeburg)	Hymenoptera	Eulophidae	parasitoid	Nystrom & Evans (1989)
	Pnigalio minio (Walker)	Hymenoptera	Eulophidae	parasitoid	Nystrom & Evans (1989)
	Zagrammosoma multilineatum (Ashmead)	Hymenoptera	Eulophidae	parasitoid	Nystrom & Evans (1989)
Scolytus multistriatus (Marsham) (Coleoptera: Curculionidae)	*Parasitaphelenchus oldhami* Rühm	Nematoda	Aphelenchoidae	parasite	Welch (1962)
Sitona cylindricollis Fåhraeus (Coleoptera: Curculionidae)	*Anaphes diana* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sitona hispidulus (Fabricius) (Coleoptera: Curculionidae)	*Anaphes diana* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sitona humeralis Stephens (Coleoptera: Curculionidae)	*Anaphes diana* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
	Anaphes fuscipennis Haliday	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
Sitona lineatus (L.) (Coleoptera: Curculionidae)	*Anaphes diana* (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sitona lineellus (Bonsdorff) [=*Sitona scissifrons* Say] (Coleoptera: Curculionidae)	*Centistes ater* (Nees) [=*Centistes excrucians* Haliday]	Hymenoptera	Braconidae	parasitoid	Loan (1964)
	Perilitus sitonae (Mason) [=*Microctonus sitonae* Mason]	Hymenoptera	Braconidae	parasitoid	Loan (1964)
	Pygostolus falcatus (Nees)	Hymenoptera	Braconidae	parasitoid	Loan (1964)
Sitophilus granarius (L.) (Coleoptera: Curculionidae)	*Bacillus* sp.		Bacillaceae	pathogen	Morris (1980)
Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae)	*Bacillus* sp.		Bacillaceae	pathogen	Morris (1980)
	Pseudomonas sp.		Pseudomonadaceae	pathogen	Morris (1980)
Sitotroga cerealella (Olivier) (Lepidoptera: Gelechiidae)	*Trichogramma minutum* Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley & Laing (1989)
	Trichogramma pretiosum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Corrigan et al. (1994)
Solidago canadensis L. (*Asteraceae*)	*Trihabda borealis* Blake	Coleoptera	Chrysomelidae	phytophage	Reid & Harmsen (1975)
	Trihabda canadensis (Kirby)	Coleoptera	Chrysomelidae	phytophage	Reid & Harmsen (1975)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
Sparaganothis distincta (Walshingham) (Lepidoptera: Tortricidae)	*Enytus* sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Triclistus sp.	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
Sparaganothis reticulatana (Clemens) (Lepidoptera: Tortricidae)	*Triclistus crassus* Townes & Townes	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
Sphenophorus australis Chittenden (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus callosus (Olivier) (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus costipennis Horn (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus destructor Chittenden (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus maidis Chittenden (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus minimus Hart. (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus necydaloides (Fabricius) [=*Sphenophorus necydaloides* Chittenden] (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus parvulus Gyllenhal (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus venatus (Say) (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Sphenophorus venatus vestitus Chittenden (Coleoptera: Curculionidae)	*Anaphes calendrae* (Gahan)	Hymenoptera	Mymaridae	parasitoid	Huber (2006)
Spilonota ocellana (Denis & Schiffermüller) (Lepidoptera: Tortricidae)	*Bassus dimidiator* (Nees)	Hymenoptera	Braconidae	parasitoid	Hagley & Barber (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Colpoclypeus florus (Walker)	Hymenoptera	Eulophidae	parasitoid	Hagley & Barber (1992)
	Triclistus crassus Townes & Townes	Hymenoptera	Ichneumonidae	parasitoid	Hagley & Barber (1992)
	Trichogramma minutum Riley	Hymenoptera	Trichogrammatidae	parasitoid	Hagley & Barber (1992)
Stethorus punctum (LeConte) (Coleoptera: Coccinellidae)	*Anthocoris musculus* (Say)	Hemiptera	Anthocoridae	predator	Robinson (1952)
	Chrysopa spp.	Neuroptera	Chrysopidae	predator	Robinson (1952)
	Orius insidiosus (Say)	Hemiptera	Anthocoridae	predator	Robinson (1952)
Tabanus affinis Kirby (Diptera: Tabanidae)	*Diglochis occidentalis* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	James (1952)
Tabanus frontalis-septentrionalis complex (Diptera: Tabanidae)	*Diglochis occidentalis* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	James (1952)
Tabanus sp. (Diptera: Tabanidae)	*Diglochis occidentalis* (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	James (1952)
	Mermis sp.	Mermithida	Mermithidae	parasite	James (1952)
Tarsonemus confusus Ewing (Trombidiformes: Tarsonemidae)	*Amblyseius fallacis* Garman	Megostigmata	Phytoseiidae	predator	Villanueva & Harmsen (1996)
Tetranychus mcdanieli McGregor [=*Eotetranychus mcdanieli* (McGregor)] (Trombidiformes: Tetranychidae)	*Adalia bipunctata* (L.)	Coleoptera	Coccinellidae	predator	Robinson (1952)
	Aeolothrips melaleucus Haliday	Thysanoptera	Aelothripidae	predator	Robinson (1952)
	Anthocoris musculus (Say)	Hemiptera	Anthocoridae	predator	Robinson (1952)
	Anystis agilis Banks	Trombidiformes	Anystidae	predator	Robinson (1952)
	Chrysopa chi Fitch	Diptera	Chrysopidae	predator	Robinson (1952)
	Chrysoperla carnea (Stephens) [=*Chrysopa harrisii* var. *externa* Hagen]	Diptera	Chrysopidae	predator	Robinson (1952)
	Chrysoperla carnea (Stephens) [=*Chrysopa plorabunda* var. *californica* Coquillett]	Diptera	Chrysopidae	predator	Robinson (1952)
	Diaphnidia pellucida Uhler	Hemiptera	Miridae	predator	Robinson (1952)
	Feltiella sp.	Diptera	Cecidomyiidae	predator	Robinson (1952)
	Haplothrips faurei Hood	Thysanoptera	Phlaeothripidae	predator	Robinson (1952)
	Hemerobius simulans Walker	Neuroptera	Hemerobiidae	predator	Robinson (1952)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Hemerobius stigmaterus Fitch	Neuroptera	Hemerobiidae	predator	Robinson (1952)
	Hyaliodes virtripennis (Say)	Hemiptera	Miridae	predator	Robinson (1952)
	Hyaloides harti Knight	Hemiptera	Miridae	predator	Robinson (1952)
	Nabis ferus (L.)	Hemiptera	Nabidae	predator	Robinson (1952)
	Orius insidiosus (Say)	Hemiptera	Anthocoridae	predator	Robinson (1952)
	Plagiognathus obscurus (Uhler)	Hemiptera	Miridae	predator	Robinson (1952)
	Scolothrips sexmaculatus (Pergande)	Thysanoptera	Thripidae	predator	Robinson (1952)
	Stethorus punctum punctum (LeConte)	Coleoptera	Coccinellidae	predator	Robinson (1952; 1953)
	Stilbus probatus Casey	Coleoptera	Phalacrididae	predator	Robinson (1952)
	Toxomerus geminatus (Say)	Diptera	Syrphidae	predator	Robinson (1952)
	Typhlodromus fallacis (Garman)	Mesostigmata	Phytoseiidae	predator	Robinson (1952)
	Typhlodromus longipilus Nesbit	Mesostigmata	Phytoseiidae	predator	Robinson (1952)
Tetranychus pacificus McGregor [=*Eotetranychus pacificus* (McGregor)] (Trombidiformes: Tetranychidae)	*Stethorus punctum punctum* (LeConte)	Coleoptera	Coccinellidae	predator	Robinson (1952; 1953)
Tetranychus urticae Koch (Trombidiformes: Tetranychidae)	*Balaustium putnami* Smiley	Trombidiformes	Erythraeidae	predator	Cadogan & Laing (1982)
	Phytoseiulus persimilis Athias-Henriot	Mesostigmata	Phytoseiidae	predator	Jones et al. (2006)
	Zetzellia mali (Ewing)	Trombidiformes	Stigmaeidae	predator	Woolhouse & Harmsen (1985)
Thymelicus lineola (Ochsenheimer) (Lepidoptera: Hesperiidae)	*Camposcopus* sp. [=*Labrorychus* sp.]	Hymenoptera	Ichneumonidae	parasitoid	Pengelly (1961)
	Casinaria sp. A [=*Horogenes* sp. A]	Hymenoptera	Ichneumonidae	parasitoid	Pengelly (1961)
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	parasitoid	Pengelly (1961)
	Meteorus hyphantriae Riley	Hymenoptera	Braconidae	parasitoid	Pengelly (1961)
	Pimpla pedalis Cresson	Hymenoptera	Ichneumonidae	parasitoid	Pengelly (1961)
	Rogas sp.	Hymenoptera	Braconidae	parasitoid	Pengelly (1961)
Tomicus piniperda (L.) (Coleoptera: Curculionidae)	*Coeloides pissodis* (Ashmead)	Hymenoptera	Braconidae	parasitoid	Bright (1996)
	Corticeus praetermissus (Fall)	Coleoptera	Tenebrionidae	predator	Bright (1996)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Dinotiscus dendroctoni (Ashmead)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
	Eupelmus sp.	Hymenoptera	Eupelmidae	parasitoid	Bright (1996)
	Eurytoma sp.	Hymenoptera	Eurytomidae	parasitoid	Bright (1996)
	Medetera pinicola Kowarz	Diptera	Dolichopodidae	predator	Bright (1996)
	Medetera signaticornis (Loew)	Diptera	Dolichopodidae	predator	Bright (1996)
	Platysoma gracile LeConte [=*Cylistix gracilis* (LeConte)]	Coleoptera	Histeridae	predator	Bright (1996)
	Rhopalicus tutela (Walker)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
	Roptrocerus xylophagorum (Ratzeburg)	Hymenoptera	Pteromalidae	parasitoid	Bright (1996)
	Spathius sp.	Hymenoptera	Braconidae	parasitoid	Bright (1996)
Tortrix sp. (Lepidoptera: Tortricidae)	*Apanteles cacoeciae* Riley [=*Dolichogenidea cacoeciae* Riley]	Hymenoptera	Braconidae	parasitoid	Laing & Heraty (1982)
Trichoplusia ni (Hübner) (Lepidoptera: Noctuidae)	*Bacillus thuringiensis* Berliner		Bacillaceae	pathogen	Jaques (1971)
	Bacillus thuringiensis Berliner *serovar. alestii*		Bacillaceae	pathogen	Angus & Heimpel (1960)
	Compsilura concinnata (Meigen)	Diptera	Tachindae	parasitoid	Harcourt (1963)
	Copidosoma floridanum (Ashmead)	Hymenoptera	Encyrtidae	parasitoid	Murillo et al. (2012)
	Copidosoma truncatellum (Dalman)	Hymenoptera	Encyrtidae	parasitoid	Harcourt (1963)
	Cotesia marginiventris (Cresson)	Hymenoptera	Braconidae	parasitoid	Murillo et al. (2012)
	Cotesia plathypenae (Muesebeck)	Hymenoptera	Braconidae	parasitoid	Murillo et al. (2012)
	Euplectrus sp.	Hymenoptera	Eulophidae	parasitoid	Murillo et al. (2012)
	Exeristes comstockii (Cresson) [=*Campoletis sonorensis* (Cameron)]	Hymenoptera	Ichneumonidae	parasitoid	Murillo et al. (2012)
	Itoplectis conquisitor (Say)	Hymenoptera	Ichneumonidae	parasitoid	Harcourt (1963)
	Meteorus sp.	Hymenoptera	Braconidae	parasitoid	Murillo et al. (2012)
	Microplitis alaskensis (Ashmead)	Hymenoptera	Braconidae	parasitoid	Murillo et al. (2012)
	Neoaplectana n. sp. (DD136)	Rhabditida	Steinernematidae	parasite	Welch & Briand (1961)
	polyhedrosis virus		*Baculoviridae*	pathogen	Cameron (1969)
	sp.	Hymenoptera	Braconidae	parasitoid	Murillo et al. (2012)
	sp.	Hymenoptera	Tachinidae	parasitoid	Murillo et al. (2012)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Stenichneumon culpator cincticornis (Cresson)	Hymenoptera	Ichneumonidae	parasitoid	Harcourt (1963)
	Trichomalopsis viridiscens (Walsh) [=*Eupteromalus viridescens* (Walsh)]	Hymenoptera	Pteromalidae	parasitoid	Harcourt (1963)
	Trichoplusia ni NPV (TnNPV)		*Baculoviridae*	pathogen	Jaques (1971)
host species not specified (Diptera: Culicidae)	*Dolichopus appendiculatus* Van Duzee	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
	Dolichopus nigricauda Van Duzee	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
	Dolichopus rendescens Melander & Brues	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
	Dolichopus walkeri Van Duzee	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
	Dugesia dorotocephala (Woodworth)	Tricladida	Duegesiidae	predator	George (1979; 1984)
	Erynia dipterigena (Thaxter) Remaudière & Keller		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Pelastoneurus sp.	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
	Thinophilus sp.	Diptera	Dolicopodidae	predator	Laing & Welch (1963)
host species not specified (Diptera: Lauxaniidae)	*Erynia echinospora* (Thaxter) Remaudière & Keller		Entomophthoraceae	pathogen	Ben-Ze'ev & Jaques (1990)
host species not specified (Hemiptera: Aphididae)	*Conidiobolus obscurus* (Hall & Dunn) Remaudière & Keller		Ancylistaceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Conidiobolus thromboides Dreschler		Ancylistaceae	pathogen	Ben-Ze'ev & Jaques (1990)
	Neozygites fresenii (Thaxter) Remaudière & Keller		Neozygiotaceae	pathogen	Ben-Ze'ev & Jaques (1990)
host species not identified (Lepidoptera/Diptera)	*Pediobius* sp. [=Pleurotropis sp.]	Hymenoptera	Eulophidae	parasitoid	Judd (1953)
host species not specified (Lepidoptera)	*Microgaster hospes* Marshall [=*Microgaster ?comptanae* Viereck	Hymenoptera	Braconidae	parasitoid	Judd (1953)
host species not specified (Orthoptera: Acrididae)	*Aerobacter aerogenes* [=*Coccobacillus acridiorum* D'Herelle]		Enterobacteriaceae	pathogen	Cameron (1969)
host species not specified	*Acholla multispinosa* (DeGeer)	Hemiptera	Reduviidae	predator	Hagley (1979)
	Allograpta olbiqua (Say)	Diptera	Syrphidae	predator	Hagley (1979)
	Anaphes alaskae Annecke & Doutt	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes amplipennis Ogloblin	Hymenoptera	Mymaridae	parasitoid	Huber (1992)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Anaphes fabarius (Rondani)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes hercules Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes hundsheimensis (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes inexpectatus Huber & Prinsloo	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes intermedius (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes medius (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes nitens (Girault)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes nunezi Ogloblin	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes pectoralis (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes pucarobius Ogloblin	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes sinipennis Girault	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes stubaiensis (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes superadditus (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes tasmaniae Huber & Prinsloo	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anaphes wolfsthali (Soyka)	Hymenoptera	Mymaridae	parasitoid	Huber (1992)
	Anatis labiculata (Say) [=*Anatis quindecimpunctata* (Olivier)]	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Anisoplia austraca Herbst		Clavicipitaceae	pathogen	Cameron (1953)
	Anthocoris nemoralis (Fabricius)	Hemiptera	Anthocoridae	predator	Hagley (1979)
	Aspergillus flavus Link		Trichocomaceae	pathogen	Cameron (1952)
	Bacillus anthracis Cohn		Bacillaceae	pathogen	Cameron (1969)
	Bacillus cereus Frankland & Frankland		Bacillaceae	pathogen	Cameron (1952; 1969)
	Bacillus proteus (Bach)		Bacillaceae	pathogen	Cameron (1952)
	Bacillus subtilis (Ehrenberg)		Bacillaceae	pathogen	Cameron (1952)
	Bacillus thuringiensis Berliner		Bacillaceae	pathogen	Cameron (1952; 1969)
	Beauveria bassiana (Balsamo) Vuillemin [=*Botrytis bassiana* Balsamo]		Moniliaceae	pathogen	Cameron (1952)
	Beauveria spp.		Clavicipitaceae	pathogen	Cameron (1969)
	Campylomma verbasci (Meyer-Dür)	Hemiptera	Miridae	predator	Hagley (1979)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Cantharis sp.	Coleoptera	Cantharidae	predator	Hagley (1979)
	Chilocorus stigma (Say) [=*Chilocoris bivulneratus* Mulsant]	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Chrysopa oculata (Say)	Neuroptera	Chrysopidae	predator	Hagley (1979)
	Coccinella novemnotata Herbst	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Coccinella transversoguttata richarsoni Brown	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Coccinella undecimpunctata L.	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Coelomegilla maculata lengi Timberlake	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Cycloneda munda (Say)	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Enterobacter aerogenes Hormaeche & Edwards [=*Aerobacter aerogenes* =*Coccobacillus acridiorum* d'Herelle]		Enterobacteriaceae	pathogen	Cameron (1952)
	Entomophthora spp.		Entomophthoraceae	pathogen	Cameron (1969)
	Eupiodes americanus Wiedemann [=*Metasyruphus americanus* (Wiedemann)]	Diptera	Syrphidae	predator	Hagley (1979)
	Haplothrips fauerei Hood	Thysanoptera	Phlaeothripidae	predator	Hagley (1979)
	Haplothrips subtilissimus (Haliday)	Thysanoptera	Phlaeothripidae	predator	Hagley (1979)
	Hemerobius humulinus (L.)	Neuroptera	Hemerobiidae	predator	Hagley (1979)
	Hemerobius sp.	Neuroptera	Hemerobiidae	predator	Hagley (1979)
	Hyalioides vitripennis (Say)	Hemiptera	Miridae	predator	Hagley (1979)
	Hyperaspis undulata (Say)	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Isaria larinosa (Holmskiold) Fries [=*Spicaria larinosa* (Holmskiold)]		Moniliaceae	pathogen	Cameron (1952)
	Mantis religiosa L.	Orthoptera	Mantidae	predator	James (1959)
	Metarrhizium anisopliae (Metchnikoff) Sorokin		Clavicipitaceae	pathogen	Cameron (1952)
	Myzia sp. [=*Neomysia* sp.]	Coleoptera	Coccinellidae	predator	Hagley (1979)
	Nabis subcoleoptratus (Kirby)	Hemiptera	Nabidae	predator	Pengelly (1961)
	Paenibacillus popilliae Dutkey [=*Bacillus popilliae* Dutkey]		Paenibacillaceae	pathogen	Cameron (1952; 1969)

APPENDIX A continued...

Host	Natural enemy	Order	Family	Feeding niche	Reference
	Pilophrous perplexus Dove & Scott	Hemiptera	Miridae	predator	Hagley (1979)
	Plagiognathus obscurus Uhler	Hemiptera	Miridae	predator	Hagley (1979)
	Podabrus sp.	Coleoptera	Cantharidae	predator	Hagley (1979)
	Podisus sp.	Hemiptera	Pentatomidae	predator	Hagley (1979)
	polyhedral virus		*Baculoviridae*	pathogen	Cameron (1952)
	Reduviuus personatus (L.)	Hemiptera	Reduviidae	predator	Hagley (1979)
	Thrips calcaratus Uzae	Thysanoptera	Thripidae	predator	Hagley (1979)
	Trichogramma evanescens Westwood	Hymenoptera	Trichogrammatidae	parasitoid	Griffiths (1972)

ONTARIO RECORDS OF *SPERCHOPSIS TESSELLATA* (ZIEGLER), A RARELY COLLECTED LOTIC WATER SCAVENGER BEETLE (COLEOPTERA, HYDROPHILIDAE)

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Scientific Note *J. ent. Soc. Ont.* 144: 113–114

Sperchopsis LeConte is a distinctive monotypic eastern North American genus of water scavenger beetles including only *S. tessellata* (Zeigler), a rarely collected species restricted to the margins of cold, clear, rapidly flowing streams where it prefers undercut sandy or gravelly banks. Spangler (1961) reviewed the distribution and biology of *S. tessellata,* recording it from the Canadian provinces of Nova Scotia and Quebec as well as from localities throughout eastern United States. Smetana (1988), in his important review of the Hydrophilidae of Canada, provides only three Canadian collection records for *S. tessellata*: one from Nova Scotia, one from Quebec and one from New Brunswick. Roughley (1991) used Smetana's review as the basis for a checklist of Hydrophilidae of Canada, but gave the known Canadian distribution of *S. tessellata* as Nova Scotia, Quebec and Ontario instead of Nova Scotia, New Brunswick, and Quebec. There are no Ontario specimens of *S. tessellata* in the Wallis-Roughley Museum of Entomology (University of Manitoba) so Roughley's listing of *Sperchopsis* from Ontario was probably a *lapsus*. The relatively large (about 7 mm long), strikingly convex, pitted adults of this species are easily distinguished from other water scavenger beetles, so it is unlikely that it would be overlooked in collections or samples from aquatic insect surveys. The new Ontario records of *Sperchopsis* given below are based on the only known Ontario collections of the genus.

I first collected and identified this species from Ontario in 1976, from the Credit River near Belfountain in Wellington County. Despite subsequent searching in apparently suitable parts of other streams and rivers in southern Ontario (including the Eramosa, Saugeen, Speed, Grand, Sauble, Rankin and Crane Rivers), no further *Sperchopsis* specimens were found until 2007 and 2008, when one beetle was found on rotting wood embedded in an undercut sandy bank in the Credit River near Erin, and another was collected in the Credit River very close to where the first Ontario specimen had been collected 31 years earlier.

Data for the Ontario specimens of *Sperchopsis*, all deposited in the University of Guelph Insect Collection, are as follows (latitude and longitude are not on the original label): Ontario, Wellington County, Belfountain, Credit River, 43°48′6.56″N 79°59′47.10″W, April 3, 1976, S. A. Marshall; Belfountain at the fork of the Credit River, May 5, 2007, Adam Brunke; Ontario, Wellington County, Credit River at the crossing of highway 124 near Erin, 43°50′6.01″N 80° 1′20.04″W, May 1, 2008, S. A. Marshall.

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FIGURE 1. Adult *Sperchopsis tessellata* from the Credit River, Ontario. Body length approximately 7 mm.

In view of the general rarity, taxonomic distinctness, and restricted habitat of this beetle, it is of potential importance as a species of conservation concern in Ontario.

Acknowledgements

Thanks to Miles Zhang for confirming that there are no Canadian *Sperchopsis* specimens in the J. B. Wallis museum.

References

Roughley, R. 1991. Hydrophilidae. Pp. 130–135 *in* Bousquet (ed), *Checklist of beetles of Canada and Alaska*. Agriculture Canada publication 1861/E.

Smetana, A. 1988. Review of the family Hydrophilidae of Canada and Alaska (Coleoptera). *Memoirs of the Entomological Society of Canada* **142**: 1–316.

Spangler, P. 1961. Notes on the biology and distribution of *Sperchopsis tessellatus* (Ziegler) (Coleoptera: Hydrophilidae). *The Coleopterists Bulletin* **15**: 105–12.

IDIOTYPA CLAVATA (PROVANCHER, 1888) (HYMENOPTERA: DIAPRIIDAE), NEW GENERIC PLACEMENT FOR A MISCLASSIFIED SPECIES

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Scientific Note *J. ent. Soc. Ont.* 144 : 115–117

In 1888, Provancher (1889) described *Camptoptera* (as "*Camptotera*") *clavata* from a male and a female collected at Ste. Gertrude, Quebec, though he did not note the actual number of specimens examined. Presumably it was only two. He also did not designate a primary type. Girault (1911) borrowed what was thought to be the unique specimen of *C. clavata,* labelled "*Camptotera clavata* Prov. 1598", but it arrived badly damaged so he could only state that it definitely did not belong to Mymaridae. Girault remounted the fragments remaining—initially stated to be "a single fore wing and several tarsi"; later in the same description corrected to "these notes are based on a fore wing and tibiae and tarsi of two legs"—in Canada balsam on a slide and described the fore wing venation and leg remnants before returning the specimen to the sender, Abbé V.A. Huard, Musée de l'Instruction Publique, Quebec [City]. Girault's designation must be construed as a lectotype designation according to ICZN Article 73.1.3 and Recommendation 73F: "Where no holotype or syntype was fixed for a nominal species-group taxon established before 2000, and when it is possible that the nominal species-group taxon was based on more than one specimen, an author should proceed as though syntypes may exist and, where appropriate, should designate a lectotype rather than assume a holotype." Gahan and Rohwer (1917) correctly treated Girault's "type" as a lectotype.

At my request, J. Perron, retired curator of the Provancher Collection, searched for the Girault slide and noted that it had been lost. So nothing at all remains of the lectotype. However, he found another specimen labeled in Provancher's hand as *C. clavata* (Fig. 1) and sent it to me for study. It is unquestionably one of the syntypes because its label number #616 (Fig. 1) corresponds to catalogue number 1598 of Provancher's personal collection, which is the number of the lost type seen by Girault (J.-M. Perron, personal communication). It is a species of *Trichopria* (Diapriidae) (Figs. 1–5), similar to *T. virginica* (Ashmead) (L. Masner, personal communication).

Peck (1963) catalogued the literature on *C. clavata*. Both he and Burks (1979) had treated the species as unplaced within Chalcidoidea, even though Girault (1911) had stated "The fore wing . . . has the venation of a Pteromalid". The question is whether Girault's brief description of those remnants actually fits that of a North American species of Pteromalidae. If the Code is scrupulously followed, only Girault's redescription of the lectotype can be used to determine the correct identity of *Camptoptera clavata*. Provancher's original description must be disregarded, because it did not explicitly include a type designation,

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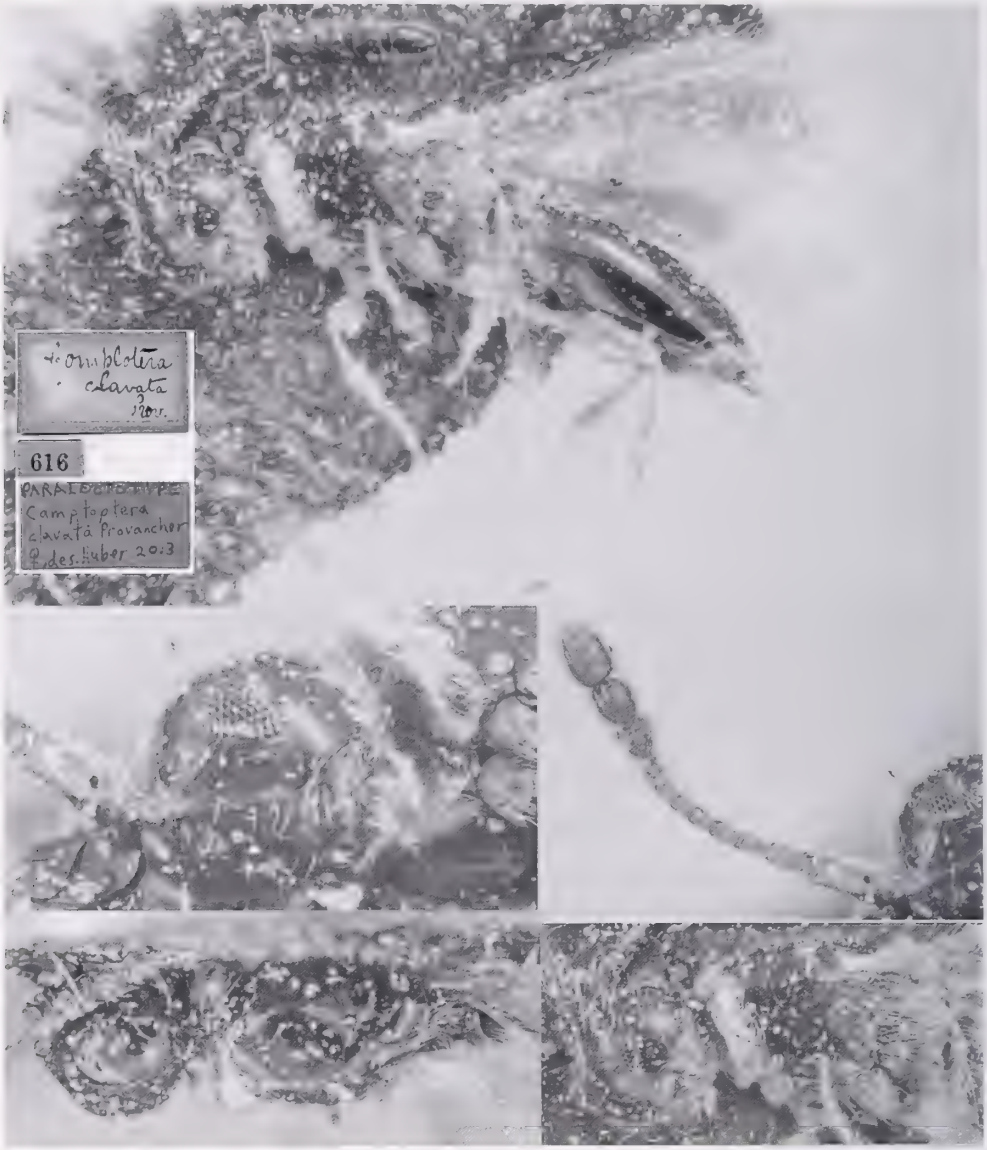

FIGURES 1–5. *Camptoptera clavata*, paralectotype female. 1, habitus, lateral; insert: labels. 2, head, anteroventral. 3, antenna, dorsal. 4, head and thorax, dorsal. Scale for Fig. 1 = 1 mm.

and the second Provancher syntypical specimen of *C. clavata* is not a name-bearing type. Yet, based on Provancher's original description and the only remaining specimen of the syntype series (the paralectotype) *C. clavata* could also be a species of Diapriidae.

Girault described the fore wing venation as "the costal cell is well developed, the submarginal vein long and slender, eight or more times longer than the short, straight, broad marginal vein, which is twice the length of the stigmal vein, which is distinct but

without a neck; postmarginal vein somewhat shorter than the stigmal and short and broad, subconic. Apex of the submarginal vein just before it joins the submarginal is colorless." No Nearctic member of Pteromalidae remotely fits Girault's description of the venation. The only Nearctic pteromalid that has a relatively short, straight and broad marginal vein is *Pachyneuron mucronatum* Girault but in this genus the submarginal vein is much less than eight times the length of the marginal which, in turn, is about as long as the stigmal vein and the postmarginal vein is longer than the stigmal vein. As for the tibia and 5-segmented tarsi, no species of Pteromalidae exactly fits Girault's description: "The tarsi are 5-jointed, with the spur forked and the strigil well-developed on the cephalic legs. The proximal tarsal joint is long. The tibiae are curved and enlarged distad, almost club-shaped. The proximal tarsal joint of the cephalic legs is curved at the base." In contrast, Girault's description fits almost perfectly species of *Idiotypa* (Diapriidae) (Masner, personal communication and my own examination of Nearctic specimens). Thus, both the lectotype and paralectotype are shown to belong to the same family, i.e., Diapriidae, though unfortunately not to the same genus. *Camptoptera clavata* is therefore removed from being an unplaced genus within Chalcidoidea, as catalogued by Peck (1963) and Burks (1979), and is here placed in *Idoiotypa* (Diapariidae) as *I. clavata* (Provancher), **comb. n.**

Acknowledgements

I thank J. M. Perron for finding and sending me the only remaining specimen of *Camptoptera clavata*, informing me about the correspondence of catalogue numbers for this species. My retired colleague, L. Masner (Canadian National Collection of Insects, Ottawa), kindly checked the generic placement of the paralectotype and suggested its likely relationships. J. Read is thanked for taking the photographs and preparing the plate.

References

Burks, B. D. 1979. Family Mymaridae. Pp. 1022–1033 *in* Krombein, K. V., Hurd, P. D. Jr., Smith, D. R., and Burks, B.D. (eds), *Catalog of Hymenoptera in America North of Mexico* **1**. Washington, DC: Smithsonian Institution Press. 1198 pp.

Gahan, A. B. and Rohwer, S. A. 1917. Lectotypes of the species of Hymenoptera (except Apoidea) described by Abbé Provancher. *The Canadian Entomologist* **49**: 298–308, 331–336, 391–400.

Girault, A. A. 1911. Notes on the Hymenoptera Chalcidoidea, with descriptions of several new genera and species. *Journal of the New York Entomological Society* **19:** 175–189.

Peck, O. 1963. A catalogue of the Nearctic Chalcidoidea (Insecta: Hymenoptera). *The Canadian Entomologist, Supplement* **30**. 1092 pp.

Provancher, L. 1989. Additions et Corrections au Volume II de la Faune Entomologique du Canada Traitant des Hyménoptères. Québec: C. Darveau. 475 pp + Errata (1 p).

NEW ONTARIO RECORDS FOR *NANOPHYES M. MARMORATUS* (GOEZE, 1777) (COLEOPTERA: BRENTIDAE), INTRODUCED INTO NORTH AMERICA FOR CLASSICAL BIOLOGICAL CONTROL OF PURPLE LOOSESTRIFE

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In 1992, *Nanophyes marmoratus marmoratus* (Goeze) (Coleoptera: Brentidae), the Purple Loosestrife Flower Weevil, native to Eurasia (Thompson et al. 1987), was identified as a candidate for biological control of Purple Loosestrife, *Lythrum salicaria* (L.) (*Lythraceae*), an alien weed invasive in North America. Although *N. m. marmoratus* was assessed as having a lower potential impact than the other biological control candidates, *Neogalerucella calmariensis* L., *N. pusilla* (Duftschmid) (Chrysomelidae) and *Hylobius transversovittatus* (Goeze) (Curculionidae), it was still released due to its high likelihood of establishment (Blossey and Schroeder 1995). From 1994–2005, *N. m. marmoratus* was released in several US states (Skinner 1996; Blossey 2001). In Canada, 720 adults were released in 1997 in southern Manitoba in three marshy sites (Lindgren et al. 2002). In Ontario there is no record of this species ever having been released (D. Mackenzie, personal communication). The present study is the first to monitor the spread of *N. m. marmoratus* in Canada since its release in North America, thus addressing Corrigan et al.'s (2013) recommendation to assess its establishment in Canada.

Nanophyes m. marmoratus adults are small (1.4–2.1 mm long), with light yellowish-brown elytral markings and a long rostrum. Females (Fig. 1a) are slightly larger and with more yellow on the elytra than males (Fig. 1b). The life cycle (egg to adult emergence) is about four weeks. The weevils first appear in mid-spring, when they mate on the flowering inflorescences before laying eggs singly in flower buds (Batra et al. 1986; Blossey and Schroeder 1995). The young whitish larvae feed on the stamens and ovary of unopened flower (Wilson et. al. 2004). The adult beetles emerge, feed on foliage and mate in late August before overwintering in leaf litter (Lindgren et al. 2002).

In 2012 and 2013 several Purple Loosestrife populations in eastern Ontario were surveyed. Only the well-established, leaf-feeding *Neogalerucella* beetles were expected to be found but *Nanophyes m. marmoratus* was repeatedly discovered as well, on Purple Loosestrife flowers from mid-June to late August. One of these specimens, from Pakenham, ON, 45.3333°N 76.2833°W, 10 September 2012 (1 female, CNC), was reported by Douglas et al. (2013) along with specimens collected in Quebec in 2011 from the area between the Ottawa and St. Lawrence Rivers (Fig. 2). *Nanophyes m. marmoratus* has now been identified at eighteen sites in eastern Ontario (Fig. 2) and quantified in fourteen of them. The average density was 0.78 (± 0.55) weevils per stem (n=513 stems), with a range of 0–14 weevils per stem.

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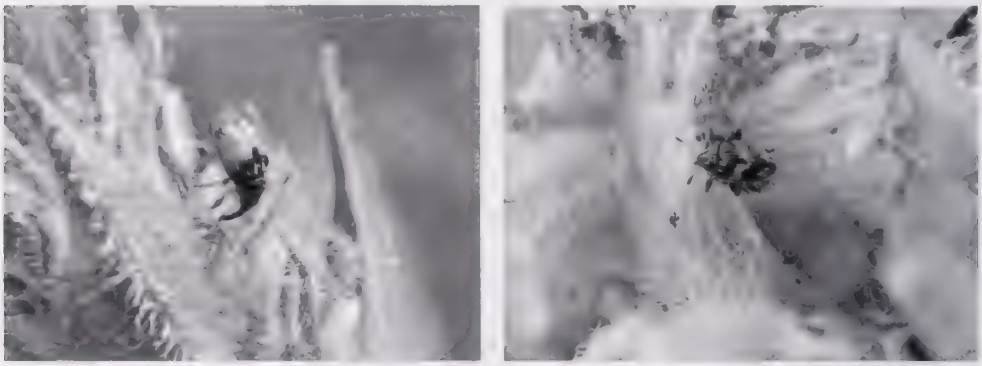

FIGURE 1a. (left) Female and 1b. (right) male *N. m. marmoratus* showing elytral patterns.

Attacked buds do not flower; they become blackened, filled with frass and usually fall off the plant (Wilson et al. 2004). In populations where *N. m. marmoratus* is common, Purple Loosestrife fruit densities are noticeably lower, with higher proportions of aborted seedpods (Fig. 3). Flower bud abortion was often seen on the lower half of the inflorescence with many to all of the buds along this section missing. Affected buds that remain on plants each have a single small exit hole—additional subtle evidence of the weevils' presence. The damaged bud can look very similar to fully developed fruits (seed capsules). Weevil damage is easily spotted and distinguishable from that caused by *Neogalerucella* beetles. The weevils' presence reduces overall seed production. At high weevil densities, larval feeding can reduce fruit output of a Purple Loosestrife plant by up to 70% (Van Dreische

FIGURE 2. Records for *Nanophyes m. marmoratus* in eastern Ontario and southwestern Quebec. Light grey points are new reports, dark grey points are those reported in Douglas (2013).

FIGURE 3. Abscission of flower buds caused by *N. m. marmoratus*.

et.al. 2002; personal observation). In the fourteen sites with *N. m. marmoratus,* reductions in reproductive output were measured as the portion (%) of the total lengths of inflorescences bearing aborted flower buds. These reductions averaged 12.6% (± 10.6%) with a range of 0–34.5% over all sites. When considering only the damaged plants (n=85) within the sites, total reproductive output reductions averaged 53% (± 26.2%) with a range of 0–100%.

Early in the biocontrol programme, it was thought likely that combining biological control agents would significantly decrease Purple Loosestrife density (Malecki et al. 1993; Blossey and Schroeder 1995; Wilson et al. 2004; Skinner 2006) but Coombs (2004) suggested that *N. m. marmoratus* would thrive when *Neogalerucella* was low or absent. At one Ontario site, anecdotal evidence suggested that obvious niche partitioning occurred; *N. m. marmoratus* was found primarily on host plants situated in a field, whereas *Neogalerucella* beetles were more concentrated on plants in the adjacent, recently-mowed, roadside ditch. The mowed plants had an increased production of tender, young shoots preferred by *Neoalerucella*, whereas unmowed plants in the field retained their flowers, preferred by *Nanophyes m. marmoratus*.

Nanophyes m. marmoratus is now present in southwestern Quebec and Ontario (Douglas et al. 2013). In Ontario, over 403 individuals were counted at 18 sites (50 vouchers, University of Ottawa). Populations of *N. m. marmoratus* are present through extensive areas of eastern Ontario, having been found along the Ottawa River watershed from above Petawawa to the National Capital Region and throughout the Rideau waterway from Kingston to Ottawa. Over the last 19 years tens of thousands of these weevils have been released and redistributed in several northeastern states (Blossey, personal communication). The origins of the Ontario populations are likely the closest US release sites, i.e., Buffalo (42.8553°N

78.8552°W) and Laurel Marsh, NY (42.8709°N 77.2424°W), about 300 km from the most southerly Ontario site at Queen's Biological Field Station (44.5681°N 76.3201°W). Though *N. m. marmoratus* dispersal has not been described, Ferrarese and Garono (2010) noted that dispersals across large expanses of open water have occurred in Oregon. They suggested that adults are capable of dispersing 100–300 km/year. Blossey (personal communication), also indicated that *N. m. marmoratus* adults are strong dispersers and have generally spread in a northeastern pattern, helped by the prevailing winds. It would be useful to survey additional areas for the presence of *N. m. marmoratus*, especially those between the original release sites in the USA and Manitoba and the sites mapped here.

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References

Batra, S. W., Schroeder, T. D., Boldt, P. E. and Mendl, W. 1986. Insects Associated with Purple loosestrife (*Lythrum salicaria*) in Europe. *Proceedings of the Entomological Society of Washington* **88**: 748–759.

Blossey, B. 2001. Impact and management of purple loosestrife (*Lythrum salicaria*) in North America. *Biodiversity and Conservation* **10**: 1787–1807.

Blossey, B. and Schroeder, D. 1995. Host specificity of three potential biological weed-control agents attacking flowers and seeds of *Lythrum salicaria* (Purple Loosestrife). *Biological Control* **5**: 47–53.

Coombs, E. M., Clark, J. K., Piper, G. L. and Cofrancesco A. F. Jr. 2004. *Biological control of invasive plants in the United States*. Western Society of Weed Science, Oregon State University Press, Corvallis, Oregon. 457 pp.

Corrigan, J., Gillespie, D. R., De Clerck-Floate, R. and Mason, P. G. 2013. *Lythrum salicaria* L., Purple Loosestrife (Lythraceae) Pp. 363–366 *in* Mason, P. G. and Gillespie, D. R. (eds) *Biological Control Programmes in Canada* 2001–2012. CABI Publishing, Wallingford, Oxfordshire, UK. 518 pp.

Douglas, H., Bouchard, P., Anderson, R. S., de Tonnancour, P., Vigneault, R. and Webster, R. P. 2013. New Curculionoidea (Coleoptera) records for Canada. *Zookeys* **309**: 13–48.

Ferrarese, E. and Garono, R. J. 2010. Dispersal of *Galerucella pusilla* and *Galerucella calmeriensis* via passive water transport in the Columbia River Estuary. *Biological Control* **52**: 115–122.

Lindgren, C. J., Corrigan, J. and De Clerk-Floate, R. A. 2002. *Lythrum salicaria* L., Purple Loosestrife (Lythraceae). Pp. 383–390 *in* Mason, P. and Huber, J. T. (eds), *Biological*

Control Programmes in Canada, 1981–2000. CABI Publishing, Wallingford, UK. 583 pp.

Malecki R. A., Blossey, B., Hight, S. D., Schroeder, D., Kok L. T. and Coulson, J. R., 1993. Biological Control of Purple loosestrife. *Bioscience* **43**: 680–686.

Skinner, L. 1996. Integrated control of Purple loosestrife in Minnesota. Minnesota Department of Natural Resources. Fifteenth North American Prairie Conference. Pp. 219–222.

Thompson, D. Q., Stuckey, R. L. and Thompson, E. B. 1987. Spread, impact and control of purple loosestrife (*Lythrum salicaria*) in North American Wetlands. *United States Fish and Wildlife Service, Fish Wildlife Research* **2**: 1–55.

Wilson, L. M., Schwarzlaender, M., Blossey, B. and Randall, C.B. 2004. *Biology and biological control of purple loosestrife*. USDA Forest Service, FHTET-04-12. 78 pp.

Van Driesche, R., Blossey, B., Hoddle, M., Lyon, S. and Reardon, R. 2002. *Biological control of invasive plants in the Eastern United States*. USDA Forest Service FHTET-2002-04. 413 pp.

FIRST RECORDS OF *ZAPRIONUS INDIANUS* GUPTA (DIPTERA: DROSOPHILIDAE) FROM COMMERCIAL FRUIT FIELDS IN ONTARIO AND QUEBEC, CANADA

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Zaprionus indianus Gupta (Diptera: Drosophilidae) was described in India (Gupta 1970) (Fig. 1) but is suspected to be native to the Afrotropical Region (Chassagnard and Kraaijveld 1996). In the New World, it was first found in late 1998 in São Paulo, Brazil and has since spread rapidly throughout South and Central America (Vilela 1999; Goni et al. 2001; Tidon et al. 2003). *Zaprionus indianus* was first detected in North America in July 2005 in Florida (Steck 2005) and is now reported from many eastern, central and southwestern states (van der Linde et al. 2006; van der Linde 2013). This species is now globally widespread and considered cosmopolitan, present in temperate and tropical regions (Tidon et al. 2003; Commar et al. 2012).

Zaprionus indianus is a generalist, with the ripe fruits of at least 74 plant species in 31 families in Africa recorded as breeding sites (Lachaise and Tsacas 1983). It has a similarly wide host range in South and North America and has become a significant pest of figs (*Ficus carica* L.) in Brazil (Santos et al. 2003; Stein et al. 2003; van der Linde et al. 2006). While *Z. indianus* is often associated with damaged or fallen rotting fruit, larvae are able to invade the soft tissue of figs before harvest and have been reared in Florida from tree-ripened *Malphigia emarginata* (Barbados cherry), *Punica granatum* (pomegranate), *Eriobotrya japonica* (loquat) and *Dimocarpus longan* (longan) (van der Linde et al. 2006; Pasini et al. 2011). In northeastern USA, *Z. indianus* has been reported in high numbers in net collected samples in a vineyard and was found in apple cider vinegar traps in cherry, raspberry and blackberry fields (Biddinger et al. 2012).

Here we report the first records of *Z. indianus* in Canada, with all specimens found in southern Ontario and Quebec. Specimens of *Z. indianus* were found during surveys for *Drosophila suzukii* (Matsumura) in apple cider vinegar traps in pre- and post-harvest fields of

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FIGURE 1. *Zaprionus indianus* from Africa dorsolateral habitus (Photograph by Stephen A. Marshall).

peach, blueberry, raspberry, strawberry, cherry and plums. Many of the Ontario specimens were collected by the Ontario Ministry of Agriculture and Food and Ministry of Rural Affairs (OMAF/MRA); all were identified by M. Miller and S. A. Marshall and deposited in the University of Guelph Insect Collection, Guelph ON (DEBU). The specimens collected in Quebec were identified at the Laboratoire de diagnostique en phytoprotection of Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), confirmed by M. Miller and S. A. Marshall, and deposited in the Collection d'insectes du Québec, Québec QC (CIQ). Voucher specimens from both provinces are deposited in the Canadian National Collection, Ottawa, ON.

Material examined. ONTARIO. **Essex.** Near Harrow, blueberries, 10.ix.2013, OMAF/MRA (1♀1♂, DEBU). Near Harrow, blueberries, 3.ix.2013, OMAF/MRA (1♀, DEBU). Near Harrow, peaches, 10.ix.2013, OMAF/MRA (21♀26♂, DEBU). Near Ruthven, peaches, 12.ix.2013, OMAF/MRA (1♀3♂, DEBU). **Chatham-Kent**. Near Blenheim, raspberries, 10.ix.2013, J. Renkema (1♀, DEBU). Near Blenheim, raspberries, 10.ix.2013, OMAF/MRA, (1♀1♂, DEBU). Near Blenheim, 2.ix.2013, J. Renkema (1♀, DEBU). **Niagara.** Near Beamsville, plums, 12.ix.2013, OMAF/MRA, (1♀1♂, DEBU). Near Niagara-on-the-Lake, cherries, 11.ix.2013, OMAF/MRA, (1♂, DEBU). **Simcoe.** Near Barrie, peaches, 10.viii.2013, H. Fraser (1♀, DEBU). **QUEBEC**. **Château-Richer**. La Côte-de-Beaupré, strawberries, 2.x.2013, MAPAQ (1♀, CIQ). **Compton**. Coaticook, raspberries, 7.x.2013, MAPAQ (1♂, CIQ). **Laval**. Laval, strawberries, 7.x.2013, MAPAQ (1♀, CIQ). Laval, strawberries, 15.x.2013, MAPAQ (1♀, CIQ). **Pierreville**. Nicolet-Yamaska, strawberries, 8.vii.2013, MAPAQ (1♀, CIQ). Nicolet-Yamaska, raspberries, 19.viii.2013, MAPAQ (1♀, CIQ). **Sainte-Pétronille**. L'Île-d'Orléans, raspberries, 3.x.2013, MAPAQ (1♀,

FIGURE 2. *Zaprionus indianus* from Ontario, Canada, male, lateral habitus.

CIQ). **Sainte-Sabine**. Brome-Missisquoi, strawberries, 6.ix.2013, MAPAQ (1♀, CIQ). Brome-Missisquoi, strawberries, 10.x.2013, MAPAQ (CIQ). **Salaberry-de-Valleyfield**. Beauharnois-Salaberry, raspberries, 17.ix.2013, MAPAQ (1♂, CIQ). **Yamaska**. Pierre-De Saurel, blueberries, 21.viii.2013, MAPAQ (1♂, CIQ).

Zaprionus indianus is the only member of *Zaprionus* Coquillett present in Canada to date. It is distinguished from all other Canadian Drosophilidae by its reddish-brown head and thorax with unique silvery stripes that extend dorsally from the antennae to the tip of the scutellum (Fig. 3) and laterally from the leading edge of the thorax to the base of each wing (Fig. 2) (Gupta 1970; Steck 2005; van der Linde et al. 2006; Yassin and David 2010). Because future invasion by other *Zaprionus* species is possible (van der Linde 2010), including the invasive *Z. tuberculatus* Malloch, currently established in Egypt and Israel, and the potentially invasive *Z. ghesquieri* Collart, introduced to Hawaii and Cyprus, but without established populations (Patlar et al. 2012; Yassin A, 2013, pers. comm.) we provide additional features that would confirm that specimens are *Z. indianus*.

The keys to African (Yassin and David 2010) and European (Bächli et al. 2004) *Zaprionus* species, the description in van der Linde (2010), and the original species description by Gupta (1970) were used to identify our specimens of *Z. indianus*. *Zaprionus indianus* specimens have 4–6 composite spines with second short branches arising directly from the fore femur (a character of all 15 members of the *vittiger* species group) (Fig. 4); the silver stripes with black borders are narrow and the black borders do not widen at the scutellum; the scutellum lacks a white tip; the abdomen is light yellow; and the subapical setae on the fourth and fifth abdominal tergite arise from dark spots. In males, the aedeagal flap is smooth apically and serrated basally (distinguishing it from *Z. africanus* Yassin and David with a deeply serrated apical margin and *Z. gabonicus* Yassin and David with a

FIGURE 3. *Zaprionus indianus*, head and thorax, dorsal view.

FIGURE 4. *Zaprionus indianus*, fore femur, lateral view, showing the composite spines.

complete lack of serration apically and basally). In females, the oviscape has six peg-like ovisensilla (*Z. africanus* with 7 or 8 ovisensilla), and the spermatheca length to width ratio is 0.95–1.16 (Gupta 1970; Steck 2005; van der Linde et al. 2006; Yassin and David 2010).

Zaprionus indianus is unlikely to become an established pest of fruit in Ontario and Quebec. The small numbers of flies we report from Ontario and Quebec suggest *Z. indianus* may have moved in from the United States in late summer and autumn 2013. However, it can adapt to a wide range of climates (Karan et al. 2000), and if it can successfully overwinter it may also spread rapidly in Canada, as evidenced by its rapid expansion in the USA since its first discovery there (van der Linde 2013). Large populations are often observed the year after its initial detection, particularly in urban environments (Ferreira and Tidon 2005). Unlike *D. suzukii*, *Z. indianus* is not known to infest ripe, undamaged fruit, but if it can use ripening fruit already attacked by *D. suzukii*, there is the potential for increased damage to harvested fruit. Therefore, future monitoring for *D. suzukii* should include *Z. indianus*. Further study on the biology and ecology of this fly is warranted, if population levels in Canada are found to increase.

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References

Bächli, G., Vilela, C. R., Escher, S. A. and Saura, A. 2004. The Drosophilidae (Diptera) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavinca* **38**. 362 pp.

Biddinger, D., Joshi, N. and Demchak, K. 2012. African fig fly: another invasive drosophilid fly discovered in PA. *Plant and Pest Advisory, Rutgers New Jersey Agricultural Experiment Station, Fruit Edition* **17**: 1–2.

Chassagnard, M. T. and Kraaijveld, A. R. 1996. The occurrence of *Zaprionus* sensu stricto in the Palearctic region (Diptera: Drosophilidae). *Annales de la Société entomologique de France (N.S.)* **27**: 495–496.

Commar, L. S. Galego, L. G. D., Ceron, C. R. and Carareto, C. M. A. 2012. Taxonomic and evolutionary analysis of *Zaprionus indianus* and its colonization of Palearctic and Neotropical regions. *Genetics and Molecular Biology* **35**: 395–406.

Ferreira, L. B. and Tidon, R. 2005. Colonizing potential of Drosophilidae (Insecta, Diptera) in environments with different grades of urbanization. *Biodiversity and Conservation* **14**: 1809–1821.

Goni, B., Fresia, P., Calvino, M., Ferreiro, M. J., Valente, V. L. and da Silva L. B. 2001. First record of *Zaprionus indianus* Gupta 1970 (Diptera: Drosophilidae) in southern localities of Uruguay. *Drosophila Information Service* **84**: 61–65.

Gupta, J. P. 1970. Description of a new species of *Phorticella Zaprionus* (Drosophilidae) from India. *Proceedings of the National Academy of Sciences, India* **36**: 62.

Karan, D., Dubey, S., Moreteau, B., Parkash, R. and David, J. R. 2000. Geographical clines for quantitative traits in natural populations of a tropical drosophilid: *Zaprionus indianus*. *Genetica* **108**: 91–100.

Lachaise, D. and Tsacas, L. 1983. Breeding sites in tropical African drosophilids. Pp. 221–332 *in* Ashburner, M., Carson, H.L. and J.N. Thompson, J.N. (eds), *The Genetics and Biology of Drosophila*. London, Academic Press. 382 pp.

Pasini, M. P. B., Link, D. and Schaich, G. 2011. Attractive solutions efficiency in capturing *Zaprionus indianus* Gupta, 1970 (Diptera: Drosophilidae) in *Ficus carica* L. (Moraceae) orchard in Santa Maria, Rio Grande do Sul, Brazil. *Entomotropica* **26**: 107–116.

Patlar, B., Koc, B., Yilmaz, M. and Ozsov, E. D. 2012. First records of *Zaprionus tuberculatus* (Diptera: Drosophilidae) from the Mediterranean Region, Turkey. *Drosophila Information Service* **95**: 94–96.

Santos, J. F., Rieger, T. T., Campos, S. R. C., Nascimento, A. C. C., Félix, P. T., Silva, S. V. O., and Freitas, F. M. R. 2003. Colonization of Northeast Region of Brazil by the drosophild flies *Drosophila malerkotliana* and *Zaprionus indianus*, a new potential insect pest of Brazilian fruticulture. *Drosophila Information Service* **86**: 92–95.

Steck, G. J. 2005. *Zaprionus indianus* Gupta (Diptera: Drosophilidae), a genus and species new to Florida and North America. *Pest Alert, Florida Department of Agriculture and Consumer Services, Division of Plant Industry*. DACS-P-01677.

Stein, C. P., Teixeira, E. P., and Novo, J. P. S. 2003. Aspectos biológicos da mosca do figo, *Zaprionus indianus* Gupta 1970 (Diptera: Drosophilidae). *Entomotropica* **18**: 219–221.

Tidon, R., Leite, D. F. and Leao, B. F. D. 2003. Impact of the colonization of *Zapronus indianus* (Diptera, Drosophilidae) in different ecosystems of the Neotropical region: 2 years after the invasion. *Biological Conservation* **112**: 299–305.

van der Linde, K. 2010. *Zaprionus indianus*: species identification and taxonomic position. *Drosophila Information Service* **93**: 95–98.

van der Linde, K. 2013. *Zaprionus indianus* distribution in the United States. http://www.kimvdlinde.com/professional/Zaprionus%20distribution%20US.php (accessed 10 October 2013).

van der Linde, K., Steck, G. J., Hibbard, K., Birdsley, J. S., Alonso, L. M. and Houle, D. 2006. First records of *Zaprionus indianus* (Diptera; Drosophilidae), a pest species on commercial fruits from Panama and the United States of America. *Florida Entomologist* **89**: 402–404.

Vilela, C. R. 1999. Is *Zaprionus indianus* Gupta, 1970 (Diptera, Drosophilidae) currently colonizing the Neotropical region? *Drosophila Information Service* **82**: 37–39.

Yassin, A. and David J. R. 2010. Revision of the Afrotropical species of *Zaprionus* (Diptera: Drosophilidae), with descriptions of two new species and notes on internal reproductive structures and immature stages. *Zookeys* **51**: 33–72.

FIRST RECORD OF *LILIOCERIS LILII* (COLEOPTERA: CHRYSOMELIDAE) EGGS IN A WILD POPULATION OF *STREPTOPUS AMPLEXIFOLIUS* (*LILIACEAE*)

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Lilioceris lilii (Scopoli) (Coleoptera: Chrysomelidae), the Lily Leaf Beetle, is an invasive European species first found at Montreal, Canada, in the 1940s (Gold et al. 2001). It is a serious pest of cultivated *Lilium* spp. and *Fritillaria* spp. (*Liliaceae*) and has spread across southern Canada and northeastern United States (LeSage 1983; Gold et al. 2001). The beetle also poses a threat to native lilies in Ontario and Quebec, including Canada Lily, *Lilium canadense* L., and Wood Lily, *Lilium philadelphicum* L. (Ernst et al. 2007; Bouchard et al. 2008). In fact, in Ontario and Quebec eight out of 20 wild populations of *L. canadense* were infested with *L. lilii* (Bouchard et al. 2008). There are also records of *L. lilii* adults feeding on plants in other liliaceous genera, e.g., *Polygonatum* (Temperé 1926; Fox Wilson 1942), *Streptopus* (Ernst 2007), as well as genera in other families, e.g., *Solanum* (*Solanaceae*) (Temperé 1926).

Kealey (2013) investigated Claspleaf Twistedstalk, *Streptopus amplexifolius* (L.) DC. (*Liliaceae*), as a potential novel host of *L. lilii*. *Streptopus amplexifolius* occurs in rich moist coniferous and deciduous woods in all provinces and territories in Canada and all adjacent states of the USA (Anonymous 2013). This native plant flowers from late spring until mid-summer. *Streptopus amplexifolius* leaves were offered to *L. lilii* larvae to determine survivorship and development time. Leaves of *S. amplexifolius* were collected from a wild population growing in Gatineau Park, Quebec, Canada (45.491°N 75.863°W). Infestations of *L. lilii* were recently reported in urban areas south of Gatineau Park, but no known *L. lilii* populations are established within the Park nor on any wild populations of *S. amplexifolius* (Cappuccino 2013).

During a routine collection of *S. amplexifolius* plants for laboratory tests on June 25, 2013, a row of three *L. lilii* eggs (Fig. 1) was discovered on the underside of a wild *S. amplexifolius* leaf. Surrounding plants were searched for more eggs, though none were discovered, nor was any obvious feeding damage by adults or larvae observed. The *S. amplexifolius* leaf with the *L. lilii* egg mass was carefully removed from the stem and transported to the laboratory. The eggs were left undisturbed, and the leaf was placed on

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moist filter paper in a 60 x 15 mm Petri dish maintained at 23°C, 70% relative humidity and 16:8 L:D, and monitored for larval hatch. The three eggs hatched on June 30th or July 1st. Two first instar larvae were still alive on July 2nd and feeding damage was observed on the leaf whereas the third larva was dead and had not fed. Subsequently both surviving larvae died. The cause of death is unclear.

The eggs (Fig. 1), and hatched larvae (Fig. 2), found in Gatineau Park shared all of the characteristics of *L. lilii*. *Lilioceris lilii* egg masses are distinct: they are laid parallel to leaf veins, in a linear arrangement of 2–16 eggs on the underside of host leaves (Salisbury 2008); eggs are bright red or orange in color, though darken when near hatching, and are covered in a sticky orange layer; individual eggs are 1.0 x 0.5 mm, and masses are laid from March–September (Haye and Kenis 2004); and *Lilioceris lilli* larvae are dirty-orange in color, with a dark head and legs. First instar larvae (Fig. 2) have head capsule widths between 0.36–0.55 mm, and a distinct egg bursting spine is located on the first abdominal segment (Livingston 1996; Cox 1994). Larvae also carry a viscous fecal shield of their own excrement on their backs.

Eggs of other genera within the Criocerinae subfamily may be confused with *L. lilii* eggs. Hosts of *Lema* spp. belong to the distantly related plant families *Solanaceae* and *Asteraceae*, and *Oulema* spp. are on species of *Asteraceae*, *Commelinaceae* and *Poaceae*. The only species of *Neolema* that occurs in Canada, *N. cordata* White, occurs on *Commelinaceae* spp. Two species of *Crioceris* closely resemble *L. lilii* in the larval stage; however, both are closely associated with Asparagales and have distinctly different egg placement and color (White 1993).

This observation marks the first record of *L. lilii* ovipositing on *S. amplexifolius* in nature and this is the first plant species outside the genera *Lilium*, *Fritillaria*, and *Cardocrinium* (the known host genera for this beetle) where both oviposition in nature and successful larval development in the lab have been observed (see Salisbury 2008). Although Ernst et al. (2007) found that larval performance was poor on *S. amplexifolius* leaves in laboratory tests, Kealey (2013) confirmed that almost half (42%) of *L. lilii* larvae can successfully develop to adults on *S. amplexifolius*. This record is also only the second oviposition record for *L. lilii* in North America on a host plant in nature outside of urban areas where development might also be occasionally possible. The observation reported here is likely the result of an adult that emigrated from an urban area. However, it is unknown what the potential is for colonization by *L. lilii* of novel host plants, such as *S. amplexifolius*, in non-urban areas. Among the factors that might encourage a more permanent move to *S. amplexifolius* by *L. lilii* is the enemy-free-space hypothesis in which the herbivore escapes its specialized parasitoid by feeding on a novel host plant (Brown et al. 1995; Rossbach et al. 2006). Further study would help to establish if such events are rare or the first step in adaptation by an invasive alien species to a novel host.

FIGURE 1. *Lilioceris lilii* eggs on *Streptopus amplexifolius* leaf from Gatineau Park, Quebec.

FIGURE 2. *Lilioceris lilii* first instar larva on a *Streptopus amplexifolius* leaf collected from Gatineau Park, Quebec. This picture was taken soon after larval death and shows A) feeding damage B) egg bursters and C) fecal shield characteristic of the species.

References

Anonymous. 2013. 2. *Streptopus amplexifolius* (Linnaeus) de Candolle, Fl. Franç. ed. 3. 3: 174. 1805. Flora of North America **26**: 145–147. Available from http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=242101972 [Accessed 22 November 2013].

Bouchard, A., McNeil, J. N. and Brodeur, J. 2008. Invasion of American native lily population by an alien beetle. *Biological Invasions* **10**: 1365–1372.

Brown, J. M., Abrahamson, W. G., Packer, R. A. and Way, P. A. 1995. The role of natural-enemy escape in a gallmaker host-plant shift. *Oecologia* **104**: 52–60.

Cappuccino, N. 2013. Lily leaf beetle tracker. Available at: http://lilybeetletracker.weebly.com/ [Accessed 8 November 2013].

Cox, M. L. 1994. Egg bursters in the Chrysomelidae, with a review of their occurrence in the Chrysomeloidea (Coleoptera). Pp. 75–100 *in* Jolivet, P. H., Cox, M. L. and Petitpierre, E. (eds), *Novel aspects of the biology of Chrysomelidae*. Kluwer Academic Publishers, Dordrecht, The Netherlands. 582 pp.

Ernst, C., Cappuccino, N. and Arnason, J. T. 2007. Potential novel hosts for the lily leaf beetle *Lilioceris lilii* Scopoli (Coleoptera: Chrysomelidae) in eastern North America. *Ecological Entomology* **32**: 45–52.

Fox Wilson, G. 1942. The lily beetle, *Crioceris lilii* Scopoli: its distribution in Britain (Coleoptera). *Proceedings of the Royal Entomological Society of London (A)* **18**: 85–86.

Gold, M. S., Casagrande, R. A., Tewksbury, L. A. and Livingston, S. B. 2001. European parasitoids of *Lilioceris lilii* (Coleoptera: Chrysomelidae). *Canadian Entomologist* **133**: 671–674.

Haye, T. and Kenis, M. 2004. Biology of *Lilioceris* spp. (Coleoptera: Chrysomelidae) and their parasitoids in Europe. *Biological Control* **29**: 399–408.

Kealey, C. D. 2013. Potential host plants of the invasive beetle *Lilioceris lilii* (Coleoptera: Chrysomelidae): implications for the biological control agent *Tetrastichus setifer* Thomson Hymenoptera: Eulophidae). B.Sc. Honours thesis. Carleton University, Ottawa, ON. 19 pp.

LeSage, L. 1983. Note sur la distribution présente et future du criocère du lys, *Lilioceris lilii* Scopoli (Coleoptera: Chrysomelidae), dans l'est du Canada. *Le Naturaliste Canadien* **110**: 95–97.

Livingston, S. S. 1996. Biological control and host range of *Lilioceris lilii*: A new ornamental pest in the USA. M.S. Thesis, University of Rhode Island, Kingston, USA. 78 pp.

Rossbach, A., Löhr, B. and Vidal, S. 2006. Parasitism of *Plutella xylostella* L. feeding on a new host plant. *Environmental Entomology* **35**: 1350–1357.

Salisbury, A. 2008. The biology of the lily beetle, *Lilioceris lilii* (Scopoli) (Coleoptera: Chrysomelidae). Ph. D. Thesis. Imperial College, London, UK. 157 pp.

Temperé, G. 1927. Régime alimentaire anormal de *Crioceris lilii* (Coleoptera Chrysomelidae). *Procès Verbaux de la Société Linnéenne de Bordeaux (1926)* **78**: 131–133.

White, R. E. 1993. A revision of the subfamily Criocerinae (Chrysomelidae) of North America north of Mexico. *United States Department of Agriculture Technical Bulletin No 1805*. v + 158 pp.

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